"To Fly and Fight":
Norms, Institutions, and Fighter Aircraft Procurement
In the United States, Russia, and Japan

by

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Submitted to the Department of Political Science
in Partial Fulfillment of the Requirements for the Degree of

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ABSTRACT

Why do states build the weapons systems they do? This study, using case studies of recent generation fighter aircraft procurement in the United States, Soviet Union/Russia, and Japan, attempts to answer this question. It concludes that no single type of explanation, or level of analysis, can completely account for the weapons design and procurement behavior exhibited in all three countries. Instead, it finds that a focus on norms and institutions can help us to organize our thinking about how various types of stimuli affect national weapons procurement processes.

More specifically, this study finds that it is most useful to examine the three cases in question using a menu of six norms: the military-technical norms of performance, cost, and delivery schedule, which have traditionally been used to analyze the weapons procurement processes of the United States and the Soviet Union, and the technonational norms of autonomy, diffusion, and nurturance, which have recently been used to describe Japan's approach to national security.

The three military-technical norms describe a superpower approach to national security which is narrowly military in nature. Performance norms clearly dominated the weapons procurement behavior of the superpowers during the Cold War era. The need to meet performance goals in response to specific threats influenced requirements-setting for aircraft in a meaningful way. The broad sense of a changed threat environment created an equally broad sense that a new aircraft must be built, and with a broadly defined set of characteristics. However, the specific decision to pull vague notions of a new threat environment and new technologies together into a new weapon system requirement at a given time, hence resolving competing claims between institutional bureaucracies, was always forced during the Cold War period by some critical event in the international system. This finding directly contradicts notions of the "technological imperative," which holds that technologies are developed by self-interested bureaucracies without legitimate rationale.
Once those U.S. and Soviet systems made their way into the procurement pipeline, however, their adherence to performance, cost, and schedule norms was critically affected by the institutional structures of the procurement processes. In particular, the competitive structure of the U.S. process led to "piling on" of technological and performance parameters, with little regard for cost or delivery norms, while the monopolistic nature of the Soviet process left it without the institutional capacity to respond to performance demands set by the armed services. Put another way, the armed services in the United States were able to use their control over information and expertise about required responses to international threats in order to maintain control over resource allocation; by contrast, the defense industrial institutions in the Soviet Union, through their control over resource allocation, dominated the Soviet procurement process.

Japan has never defined its security in such narrow military-technical terms. Japan adheres to norms of indigenization or autonomy with regard to technological development, diffusion of those technologies throughout the military and commercial sectors, and nurturance of national institutional capacities to develop and harness technologies toward strategic goals. Attention to performance, cost, and delivery schedules in Japan has been readily neglected or sacrificed in favor of a more comprehensive approach to national security.

After the Cold War, the American, Russian, and Japanese normative structures seem to be converging. In order to maintain defense industrial capacity, the United States and Russia have adopted various institutional strategies which embody the norms of diffusion and nurturance; both of the former superpowers have even shown some evidence of willingness to sacrifice a degree of autonomy in order to keep defense industrial capacity healthy. Institutional structures in Russia have been shattered virtually overnight, paving the way for a new set of normative influences to emerge from the rubble. On the other hand, U.S. weapons procurement institutions are both resisting and being affected by the shift toward what might evolve into a more comprehensive approach to American national security.

The degree of change in Japan's normative framework as a consequence of the end of the Cold War is more difficult to fathom. Japanese devotion to autonomy, diffusion, and nurturance predates the Cold War; it seems likely that an increase in attention toward any of the three military-technical norms in the post-Cold War world will take place within the relatively stable context of technonationalism.

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Biography of author

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Chapter One:
Levels of Analysis, Institutions, and Norms

Why do states build the weapons systems they do? What determines when and how new systems are proposed, designed, and manufactured? Why do weapons systems look the way they do when they emerge from the procurement pipeline; in other words, why are certain sets of technical and tactical choices made over others? What determines the pace and scope of developing and harnessing new technologies during the process of procuring weapons? Why do different countries' weapons development processes, which are constrained by the same laws of physics, seem sometimes to create and use technology in such different ways? Are the same factors capable of explaining weapons system choices and development cross-nationally, or do different explanations apply in different cases? This study, using case studies of recent generation fighter aircraft procurement in the United States, Soviet Union, and Japan, attempts to answer these questions. It starts with an examination of the various types of explanations scholars have used to address these issues in the past, and analyzes those explanations in terms of the debate over appropriateness of levels of analysis.

It concludes that no single type of explanation, or level of analysis, can completely account for the weapons design and procurement behavior exhibited in all three countries. Instead, it finds that a focus on norms and institutions can
help us to organize our thinking about how various types of stimuli affect national weapons procurement processes. Norms which have been passed down through generations of accumulated historical experience broadly inform the way a state conceptualizes its definition of national security and the appropriate means for maintaining that security. Norms critically shape the institutions which implement national security goals; conversely, over time, institutional structures inherited from the past constrain and shape the ways in which norms evolve. Furthermore, institutional structures act as a prism which refracts the ways in which inputs from the international system and from domestic-level processes can affect weapons procurement behaviors.

More specifically, this study finds that it is most useful to examine the three cases in question using a menu of six norms: the military-technical norms of performance, cost, and delivery schedule, which have traditionally been used to analyze the weapons procurement processes of the United States and the Soviet Union, and the technonational norms of autonomy, diffusion, and nurturance, which have recently been used to describe Japan’s comprehensive approach to national security. A focus on these norms, and the institutional structures which both shape and are shaped by them, can also help us to understand the ways in which each country’s weapons procurement dynamics and the broader conceptualizations of national security which drive that behavior may be changing in
the post-Cold War world.

The three military-technical norms describe a superpower approach to national security which is narrowly military in nature. Performance norms clearly dominated the weapons procurement behavior of the superpowers during the Cold War era. The need to meet performance goals in response to specific threats influenced requirements-setting for aircraft in a meaningful way. The broad sense of a changed threat environment created an equally broad sense that a new aircraft must be built, and with a broadly defined set of characteristics. However, the specific decision to pull vague notions of a new threat environment and new technologies together into a new weapon system requirement at a given time, hence resolving competing claims between institutional bureaucracies, was always forced during the Cold War period by some critical event in the international system. This finding directly contradicts notions of the "technological imperative," which holds that technologies are developed by self-interested bureaucracies without legitimate rationale. Recent-generation Soviet and American fighter aircraft were catalyzed by specific threats.

Once those U.S. and Soviet systems made their way into the procurement pipeline, however, their adherence to performance, cost, and schedule norms was critically affected by the institutional structures of the procurement processes. In particular, the competitive structure of the U.S. process
led to "piling on" of technological and performance parameters, with little regard for cost or delivery norms, while the monopolistic nature of the Soviet process left it without the institutional capacity to respond to performance demands set by the armed services. Put another way, the armed services in the United States were able to use their control over information and expertise about required responses to international threats in order to maintain control over resource allocation; by contrast, the defense industrial institutions in the Soviet Union, with their de facto control over resource allocation, dominated the Soviet procurement process.

Japan has never defined its security in such narrow military-technical terms. The data presented here support an argument that Japan adheres to norms of indigenization or autonomy with regard to technological development, diffusion of those technologies throughout the military and commercial sectors, and nurturance of national institutional capacities to develop and harness technologies toward strategic goals. Attention to performance, cost, and delivery schedules in Japan has been readily neglected or sacrificed in favor of a more comprehensive approach to national security.

After the Cold War, the American, Russian, and Japanese normative structures may be converging. Clearly performance norms are no longer as critical for a United States and Russia who no longer define one another as deadly enemies; although
certainly to varying degrees, the decline in resource allocations to defense has forced all three countries to pay more heed to cost considerations. In order to maintain defense industrial capacity, the United States and Russia have adopted various institutional strategies which embody the norms of diffusion and nurturance; both of the former superpowers have even shown some evidence of willingness to sacrifice a degree of autonomy in order to keep defense industrial capacity healthy. Institutional structures in Russia have been shattered virtually overnight, paving the way for a new set of normative influences to emerge from rubble. On the other hand, U.S. weapons procurement institutions are both resisting and being affected by the shift toward what might evolve into a more comprehensive approach to American national security.

The degree of change in Japan's normative framework as a consequence of the end of the Cold War is more difficult to fathom. Japanese devotion to autonomy, diffusion, and nurturance predates the Cold War; it seems likely that an increase in attention toward any of the three military-technical norms in the post-Cold War world will take place within the relatively stable context of technonationalism.

Before presenting the evidence to support these findings, this study first examines the theoretical underpinnings behind the various levels of analysis, and highlights recent attempts
to combine the levels in interesting and useful ways. Its methodology is to make predictions based on the theoretical premises of each level of analysis, and of the theories that combine them, and then to examine the data to determine which set of predictions is confirmed by the evidence, and under what circumstances. It will do so for each case study individually, and then draw some concluding observations about appropriate directions for further study, and possible predictions based on this work.

The Levels of Analysis Problem

In addition to answering specific questions about weapons procurement, this work hopes to make a general contribution to the debate over appropriate levels of analysis in international relations. The level of analysis at which an activity is discussed distinguishes between those theories that treat the organization, in this case the state, as an undifferentiated collectivity responding to its external environment, and those which deal with smaller social structures within organizations, such as individuals, coalitions, and subunits.¹

A state operates in two different arenas: in its external environment as a state among states, and in its internal

environment as a large political organization. For many years, analysts seemed to prefer to examine phenomena in light of one or another particular level of analysis, attempting to demonstrate the explanatory power offered by that unique set of tools -- that is, if they acknowledged the levels of analysis problem at all. The literature on weapons procurement is no exception. Only recently has the methodology of the study of international relations reached the point where the explanatory powers of these theories are explicitly tested against one another, either by identifying defects in one theory by confronting it with incompatible claims made by another, or by comparing the predictions made by the various theories with observed outcomes.

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4 See, for example, Barry Posen, *The Sources of Military Doctrine: France, Britain, and Germany Between the World Wars*, Cornell University Press, Ithaca, 1984. Efforts to achieve decisive tests between levels of analysis, however, may be only superficially appealing. According to Philip Tetlock, by creating
Selective use of data, however, could easily prove that virtually any theory is applicable to every case to some degree. Obviously no one set of causal factors is by itself sufficient to capture the full range of complexities of any topic under discussion. Even the pioneering treatment of the level of analysis problem recognizes the tension in an exclusive focus on either the international or domestic level.\(^5\) Singer in 1961 suggested that the levels be integrated somehow, but was content simply to observe that no one had done it up to that point.

Thirty years later, it is time to go beyond the one-theory/one-case-study approach. Many scholars now agree that the explanatory power of any given level of analysis is not a constant, but is likely to vary as a function of the configurations of variables at other levels and the types of questions that are being asked.\(^6\) Each level of analysis has something important and unique to offer. Systems theories explain why different units behave similarly; theories at the unit level tell us why different units behave differently

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\(^6\) Tetlock, p. 339.
despite their similar placement in a system. While structural realism has the benefits of parsimony and clarity, the range of phenomena it encompasses is limited. Systemic theory remains important, however, because the context of action must be understood before the action itself can be understood. Similarly, while complex theories of domestic politics, decision making, and information processing help us organize and understand the details of within-state processes, a focus only on the "trees" might neglect important stimuli coming from outside the "forest."

This study attempts to bridge the gap between external and internal environments in a systematic way. It explicitly tests theories derived from the international systemic and domestic levels of analysis which have traditionally been employed in research on international behavior, and more recent approaches which have tried to elucidate the dynamics of their interaction. Its key questions are therefore the following: do the predominant inputs and processes shift according to time and context? How? Do decision outcomes differ as inputs and processes change? How?

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contextual lenses lead to different judgments about what is relevant and important, and under what circumstances.\textsuperscript{10}

This kind of approach is particularly important in the study of national security policies. Because the state sits at the nexus of the international and the domestic, it is important that our theories recognize that a state's security policies are a product of its dual responsibilities. One way to link the levels of analysis is to recognize that security policy itself is two-faced -- it involves the construction of strategies vis-a-vis foreign threats, and also the mobilization of domestic resources to meet those threats. Thomas Risse-Kappen, for example, examining the factors that led to the conclusion of the INF treaty, finds that both the United States and the Soviet Union reacted to international system influences, but in ways determined by domestic political coalition-building processes.\textsuperscript{11} Michael Barnett and Jack Levy obtain similarly theoretically pluralistic results in their study of Egyptian security policy in the 1960's and early 1970s: alliance formation behavior was determined by an international systemic component that specified the degree of the perceived external security threat, the availability of international allies, the nature of the political and economic goods that allies might provide, and the autonomy costs that

\textsuperscript{10} Tetlock, p. 340.

must be sacrificed in return for alliance formation; but the
domestic component determined the domestic objectives of state
actors, the social, economic, and political constraints that
limited the availability of resources, and the government's
access to those resources at acceptable cost.\textsuperscript{12}

Even these efforts, however, simply state the obvious --
that both levels of analysis matter -- and do not attempt to
make contingent generalizations about when and under what
conditions this is true. Thomas Christensen and Jack Snyder,
also examining alliance behavior, do draw such generalizations
-- that the relevant contextual variable is the domestic-level
factor of perception of offensive or defensive advantage, and
that perceptions of offensive advantage are associated with
chain-ganging behavior, while perceptions of defensive
advantage are associated with buck-passing.\textsuperscript{13}

This work therefore approaches the case study data on
fighter aircraft procurement inductively, with the goal of

\textsuperscript{12} Michael N. Barnett and Jack S. Levy, "Domestic Sources of
International Organization, Vol. 45, No. 3, Summer 1991, pp. 369-
395.

\textsuperscript{13} Thomas J. Christensen and Jack Snyder, "Chain Gangs and
Passed Bucks: Predicting Alliance Patterns in Multipolarity,"
International Organization, Vol. 44, No. 2, Spring 1990, pp. 137-
168. For other excellent examples of theoretical pluralism in the
recent security studies literature, see Michael Barnett, "High
Politics Is Low Politics: The Domestic and Systemic Sources of
4, July 1990, pp. 529-562; and Jeffrey Checkel, "Ideas, Institutions,
and the Gorbachev Foreign Policy Revolution," paper presented at the
1991 Annual Meeting of the American Political
Science Association.
ascertaining possible patterns of relevance among international systemic and domestic theories. Because the field of political science is aggressively deductive, it may be appropriate at this point to comment on the primarily inductive methodology used here. The choice between a strictly deductive or inductive method is in some senses an artificial one. We need some sense of the connection of things and events before we can worry about constructing theories. At the same time, we need a theory, or some theories, in order to know what kind of data and connections to look for. Knowledge, it seems, must precede theory, and yet knowledge can only proceed from theory.

This paradox is solved in this work through the nature of the task at hand. Existing theories are outlined, specific predictions made from them, and the theories tested in a deductive manner. The final goal, however, is not simply to say that one is more "correct" than the other, but instead to search for useful ways of combining them. For example, are chronological factors prominent; that is, are some explanatory variables more relevant at some stages of the weapons procurement process than others? Perhaps contextual factors dominate; in that case, some of the competing independent variables will demonstrate more explanatory power under certain domestic or international conditions than under other circumstances. The search for contextual factors which may determine when and under what conditions either level of
analysis is more appropriate must be accomplished inductively. Ultimately, this work does explicitly what virtually all theoretically-grounded research does implicitly -- it coasts back and forth between induction and deduction, constructing or refining theory and constantly confirming the appropriateness of the theory against the relevant data. The explicit goal of this work is to go beyond the either-or application of levels of analysis in an attempt to construct a comprehensive framework that might be applicable across time and across cases, or perhaps to discover that national differences make such a framework impossible.

The Cases

In order to draw potentially universally applicable cross-theoretical generalizations, more than one data set must be consulted. The method used here is that of controlled, focused comparison as outlined by Alexander George. The task of this method is to convert the lessons of case research into comprehensive theory, and to state those lessons in a systematic and differentiated way. This familiar analytical


inductive approach to theory development, asking the same set of standardized, theoretically-derived questions of each case study, is necessary to permit comparison and cumulation of findings. The heuristic type case study is used here, to stimulate the imagination to discern new general problems, identify possible theoretical solutions, and formulate potentially generalizable relations that were not previously apparent. The case study is therefore used as a "building block" in the construction and development of theory. In this study, the set of "questions" asked of each case will simply consist of the predictions derived from international and domestic level theories. Do these predictions conform with the data at hand? Are there apparent contextual patterns determining when one of the other level of analysis is most appropriate? Are these patterns applicable cross-nationally, or are they state-specific?

The selection of the Soviet and American case studies has been made for obvious reasons; these are the two traditional military superpowers, with the world's largest and technically most sophisticated arsenals. The Japanese case has been added because of the possibility of Japan emerging as a military power in the coming decades, and because of its tremendous potential for technological dominance. Also, the purported role of the state in shaping Japan's economy, particularly where technical innovation is concerned, provides an interesting and possibly illuminating middle ground to the
extremes of the American market economy (although it is clear that the defense sector, with a single customer and oligopoly suppliers, is the least market-oriented environment in the U.S. economy) and the Soviet planned economy.

The choice of recent-generation fighter aircraft as the weapon system to be studied follows from the fact that aircraft embody highly advanced state-of-the-art technology, and therefore will capture the essential dynamics of high technology; that aircraft represent the one military-technological realm in which all three countries under consideration are most tightly competitive; that Air Forces traditionally embody a strong sense of military and military service tradition which may render organizational variables easier to operationalize and detect; and that the selection of a recent case study makes it possible to speculate on changes in weapons procurement dynamics in the post-Cold War period.

**International Systems Level Theory**

The conceptual cornerstone of international system theories lies in the notion of rational strategic choice by governments behaving as actors in the anarchical international system. All states are potential threats to others, with no international sovereign to mitigate disputes. Each state must therefore take measures to ensure its own survival, selecting

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specific weapons and total force posture on the basis of precise calculations about national objectives, perceived threats, and strategic doctrine within the constraint of technology and budgets. Government action according to this model is conceived of as consistent and purposive choice, with individual and organizational factors ignored or downplayed as less important than the primary impact of the external stimulus provided by the environment of the international system.

In this context, the most "rational" approach to weapons procurement would identify national goals, derive missions from them, investigate existing and new technologies to specify options, and make choices best suited to fulfill those missions. Ideally, the notions of military need and technical opportunity are rationally iterated, since the military service as the user of a weapon system cannot precisely define what it really wants until it understands what it can feasibly have, technically, fiscally, and politically, and the weapons developer cannot specify a product without a clear understanding of its purpose and the context of its eventual

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use.  

A prominent variant of the rational actor hypothesis is the action-reaction, or arms race model. The broad outlines of this theory hold that each state watches the behavior of others very closely, and may be expected to react to programs, deployments, or signals of foreign policy intentions that could rebound to its relative disadvantage. Because of the length of the acquisition process, however, it is frequently not the actual deployment of new weapons but even scant evidence of R&D on new programs that can create apprehension about the future and stimulate a counter-reaction. The years that separate prototype testing from deployment provide time for the threat to be exaggerated and then offset. This pattern of continuous worst-case analysis can lead to a spiral of military-technical innovations designed to counteract future developments which the opponent may or may not actually develop the capability or the inclination to deploy.

The secrecy surrounding military technological developments plays a large role here, of course, contributing greatly to mutual suspicion and apprehension about technical surprise. If there is any doubt about the capabilities or intentions of the adversary, military prudence dictates worst-

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case planning, with the extent of the overreaction directly dependent on the degree of uncertainty about that adversary. At some point, the task of distinguishing the action from the reaction becomes difficult, since the deployed response to "potential" enemy developments may precede the stimulus that prompted it, and since that stimulus may actually never materialize at all.\textsuperscript{20}

Analysts have derived many variations from the action-reaction pattern. Reactions may involve single weapons systems, similar or dissimilar systems, overall force postures, or even defense expenditures. Other variables include the magnitude of the response, which may vary with relative starting positions; the timing of the response, which, as discussed above, may be anticipatory; and the degree to which states are aware that they are involved in an action-reaction dynamic.\textsuperscript{21}

The action-reaction process may also be purely imitative, fueled by the power of suggestion. One side may assume that to excel over an enemy, it must excel in every dimension. If the enemy makes progress in a particular direction, he must have some good reason for doing so, and therefore his progress in that direction must be equalled or bettered. Enemy action may serve as a reminder of things that have been overlooked or paid too little attention to, or it may simply give an

\textsuperscript{20} Allison and Morris, p. 118.

\textsuperscript{21} Gray, 1976.
indication of what can be done.\textsuperscript{22}

**International Systemic Factors Quantified**

A great deal of intellectual effort has been expended in attempts to quantify action-reaction and arms race dynamics. The first attempt, and still the basis for all other endeavors in this direction, is the Richardson equations.\textsuperscript{23} Richardson argued that annual changes in a country's defenses (measured most simply as defense budgets) are a function of three basic variables: the size of the enemy's defenses, the fatigue or expense of maintaining certain levels of defenses, and the level of grievance or ambition felt toward the enemy. He expressed this idea mathematically as follows:

\[
\begin{align*}
\frac{dx}{dt} &= ky - \alpha x + g \\
\frac{dy}{dt} &= lx - \beta y + h
\end{align*}
\]

where \(x, y\) = a country's defense expenditures  
\(k, l\) = positive defense coefficients  
\(\alpha, \beta\) = positive constants representing fatigue and expense of keeping up defenses  
\(g, h\) = grievances and ambitions if positive, or "contentment" if negative.

The units of coefficients \(k\) and \(l\) are obviously reciprocals of time; \(1/k\) is the apparent catching up time in an arms race from a starting point of zero with no grievances.


\textsuperscript{23} Lewis F. Richardson, *Arms and Insecurity*, Boxwood Press, Pittsburgh, 1960.
The time required for this catch-up would logically vary with a country's population and industrial resources; therefore, other things being equal, k and l are defense coefficients proportional to defense industrial capability.

Richardson goes on to elaborate possible variants of this model, including conditions of stability and the effects of attempts to impose or control stability for a system described by these types of equations. One variant, for example, hypothesizes that nations might respond not to the absolute numbers of forces or budgets possessed by the other side, but to the differences between itself and its rival. In this case, the equations can be easily modified:

\[
\begin{align*}
\frac{dx}{dt} &= k(y-x) - ax + g \\
\frac{dy}{dt} &= l(x-y) - by + h
\end{align*}
\]

Countless efforts have been made to revise and expand the original Richardson framework, with modifications including the effect of scarce resources, ties to the domestic economy, the utility of optimization tradeoffs for countries, military strategy, races with strategic vs. conventional weapons, nation systems and alliances, psychological factors, and world

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system effects.

This study simply acknowledges that these quantitative efforts to analyze arms race behavior exist. It does not use them as its primary mode of analysis for two reasons. First, this study focuses on the qualitative aspects of arms race behavior (weapon systems choices rather than numbers of weapons), which are particularly difficult to quantify consistently. Second, the state of the art of quantifying arms race dynamics is not sufficiently advanced to warrant its playing a prominent role in a study of this type. For example, Charles Ostrom tests the Richardson equations against an organizational politics model taking Office of Management and Budget-requested and Congressionally appropriated appropriations into account, and then compares those results to a naive model assuming that this year's budget depends only on last year's budget plus a randomly-generated disturbance term. It turns out that neither substantive model is particularly accurate, and that neither produces results substantially different from the naive model. The equations as they are currently developed rely largely on the past to predict the future, with slim consideration of exogenous variables. This, it seems, points to the need for much further research into the precise dynamics of the processes of national weapons procurement.

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behavior, on a case study basis, before the prerequisite foundation can be considered adequate to proceed with quantitative models of the process. Hence, this study.

Application of International Systems Models to Weapon System Choices

Official Description of the Process: The formal Department of Defense description of the weapons procurement process implicitly follows an international systems model. Ronald Fox, for example, outlines the first few stages of the process as follows:

1. The Department of Defense identifies a security threat or defense need.
2. The Department designs an engineering development program to meet the need and draws up a budget.
3. Congress authorizes and appropriates funds for the engineering development program.
4. The administration releases funds for the program.

In other words, the officially established process places the determination of a weapon system requirement entirely in the hands of the Pentagon, which responds solely to tactical or technical threats it identifies in the international environment.

Action-Reaction Dynamics: The legitimacy of the action-reaction hypothesis peaked among analysts in the late 1960's attempting to explain nuclear weapons developments and deployments. George Rathjens, for example, describes a few

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legs of the nuclear arms race: the perceived "missile gap" of the 1960's led the United States to build a large fleet of intercontinental ballistic missiles. The Soviets responded to American ICBM's, and also to the threat from B-70 bombers and SR-71 strike-reconnaissance aircraft, by building the Tallinn and Moscow air defense systems. This in turn led the Americans to develop multiple-warhead missiles and a new generation of ICBM's.\textsuperscript{27}

Secretary of Defense Robert McNamara was the first explicitly and publicly to pinpoint the action-reaction phenomenon in a 1967 speech to United Press International editors in San Francisco. He said, "Whatever be their intentions, actions - or even realistically potential actions - on either side relating to the build-up of nuclear forces, be they offensive or defensive weapons, necessarily trigger reactions on the other side. It is precisely this action-reaction phenomenon that fuels an arms race."\textsuperscript{28}

The Sources of Weapons Procurement Choices: Predictions from International Systems Theories

If variables based on external factor theories are dominant relative to this particular case, the development of recent-generation fighter aircraft, what should the case study


\textsuperscript{28} McNamara, \textit{Department of State Bulletin}, October 9, 1967, pp. 443-451.
data be expected to show? The following behaviors might be predicted:

I-A: States will undertake extensive analyses of the threat, in this case, of the technical, tactical, and operational challenges presented by the opponent's current and projected developments in fighter aircraft.

I-B: Technical developments will not "bubble up" from research laboratories, but will instead be driven by requirements set by political and military officials who have analyzed the threat.

I-C: Those political and military officials may take advantage of technical opportunities created by the laboratories, but only if the threat environment dictates that they should do so. Scarce resources will not be wasted pursuing technology for technology's sake.

I-D: Developments in the enemy's tactics will receive as much attention as developments in his technology, since the manner in which his weapons are intended to be used will provide guidelines for assessing the most rational technical and tactical responses.

Conversely, patterns we should expect to find if international systems explanations are not appropriate include the following:

I-E: Weapon systems will make their way through the procurement pipeline without a legitimate threat to which they are responding.

I-F: Little attention need be paid to assessments of the enemy's tactics or technology.

I-G: It is possible that conversation, even urgent warnings, about the nature of the external threat will still characterize the weapons procurement process. The timing of that conversation will be critical; if threats are being trumped up as mere rationale for developing the system for other reasons, those invented threats will tend to emerge after the system has already gone through the early stages of development.
Domestic-Level Factors

Domestic or internal factors explanations focus on the dynamics of within-state stimuli and processes. The complexity of within-state behavior has led to a variety of analytical models to account for that behavior. This study addresses bureaucratic politics models and theories of organizational politics.

Bureaucratic Politics

Bureaucratic politics models tend to focus on the individual person, or flexible coalitions of people, as the primary unit of analysis. They stress bargaining along regularized circuits among players positioned hierarchically within the government. Government behavior is therefore the result of bargaining games, where the players have various conceptions of national, organizational, and personal goals.\(^{29}\) Sometimes one group committed to a course of action triumphs over other groups fighting for other alternatives; sometimes different groups pulling in different directions produce a resultant, a mixture of the conflicting preferences and unequal power of various individuals, different from what any one person or group intended. The critical variables are the political power and skill of the proponents and opponents of

the action in question. It is therefore necessary when employing this model to identify the games and the players, and the relevant coalitions, bargains, and compromises.\textsuperscript{30}

When playing these bureaucratic games, officials distort information they pass upward in the hierarchy, exaggerating data favorable to themselves and minimizing those unfavorable. They are biased in favor of policies and actions that advance their own interests or those of the programs they advocate, and against those that injure or fail to advocate those interests.

In terms of weapons acquisition, the bureaucratic politics model holds that weapon systems choices are a political resultant, the outcome of explicit or tacit bargaining between political participants who share power. Arms procurement is managed and driven by officials in various positions of authority within national bureaucratic structures. Technical advances and weapon system choices are the result of negotiated or legislated domestic contention. No single, rational strategic calculus prevails; instead, ideas are the servant of bureaucratic interests, with every interest finding a doctrinal creed as its rationale. Internal contests for power and influence, and factional considerations, are crucial.

As significant military-technical ideas and discoveries are produced, specialized coteries of individuals and groups

\textsuperscript{30} Allison, \textit{Essence of Decision}, p. 177.
coalesce around the weapons system and develop, even in the early phases of the process, a vested interest in its ultimate adoption. Scientists are responsible for the original discovery, private interests anticipate lucrative contracts as producers of the new weapon, and agencies and institutions sponsor the original research. At this early stage, strategic or tactical rationales for the weapon may develop, even independently of the military itself. Soon, the coalition swells to include the military, and then hardline political supporters and public opinion. The military requirements process invites players to sign on, and is so lengthy and elaborate that it provides ample opportunity for players to do so. What therefore emerges are systems which embody the "state of the art" in every single component, because new technological advances must be incorporated for every player who has to be co-opted.

Bureaucratic Politics: The Technological Imperative

An interesting subset of the bureaucratic politics model is the technological imperative model, in which systems are built simply because of the irresistible lure of technological advances. According to this theory, the organization of military research creates irresistible pressures to get the resulting hardware into production. Research is funded with

the expectation that the final result will be converted into a fully operational weapon system. When force levels are relatively stable, service technical organizations and their clients can guarantee their own survival only by generating a continuous stream of qualitative improvements to make existing deployments obsolete.

This whole process is said to be driven by a military requirements system largely based on fiction. Both the threat and the requirement are invented to provide a rationale for a development program that was actually started for other reasons, perhaps to perpetuate existing organizations, or to exploit a "sweet" technological concept. Military requirements and evidence of military developments abroad therefore become after-the-fact rationalizations of technical ideas cooked up at a relatively low level in the military-technical-contractor bureaucracy. Even annual posture statements are often rationalizations of existing development programs.\(^{32}\) New technological ideas are, along with threat assessments, units of currency in the bureaucratic game.

The bureaucratic interests of military scientists and engineers play the dominant role in technological imperative theories. The scientist can play two roles in his career -- lobbyist or innovator. While acting as the former, he is acting in the political realm; in the latter, more purely

technological. As a lobbyist, he needs institutional backing, a requirement for his professional advice, and an ability to publicize his views. The scientist's relationship with politicians is the single most important determining factor in his ability to influence policy. He interacts with the government as an individual expert whose strength and influence derives from his ability to meet the needs of his political superiors. Defense researchers and engineers promote their own ideas, stemming from defense contractors and the government's own armed services and civilian weapons laboratories, because they have a bureaucratic stake in sustaining the system of weapons innovation. Their guiding forces are a combination of professional ambition, ideological conviction, and a taste for technological sweetness. Sometimes this phenomenon is exacerbated by inter-service rivalry, as the services ally with particular scientists of particular laboratories to push their own rights to certain weapons systems.

The scientists and engineers are particularly successful at this bureaucratic game because of their unique expertise. Anyone who disagrees with them is said to be unable to


understand the situation, technically backward, and trying to put the budget ahead of survival.\textsuperscript{35} Scientists and engineers have acquired the reputation for being magicians who are privy to some special source of information and wisdom out of reach of the rest of mankind. They themselves often believe that only they understand the problem. In the face of technical complexities and conflicting advice, the non-scientist decision-maker may be tempted to defer to the judgment of scientists on questions which may nevertheless hinge basically on political factors.\textsuperscript{36}

Application of Bureaucratic Models to Weapon System Choices

Expanding Bureaucratic Turf: Birth of the SDI: Several analysts have illuminated case studies of weapons procurement processes using variants of the bureaucratic politics model. Erik Pratt, for example, attempts to explain the history of ballistic missile defense in the United States using what he terms elite network analysis, a simple twist on the bureaucratic politics paradigm.\textsuperscript{37} According to Pratt, the defense policy formation process includes formal decision-


making procedures set forth in government regulations, and also a broader network of influential individuals, both in and out of government, who form a defense policy network. This network reveals actual and potential elite interactions both inside and outside of organizational structures. In Pratt's bureaucratic framework, the complex interactions between elites and organizational structures can lead to three possible outcomes. The elite interests can either dominate organizational interests, orchestrate organizational interests, or wind up subordinate to organizational interests. This defense policy network shapes the weapons acquisition process by determining which issues reach the official agenda, who participates in the policy process, and who has relative political capacities, ideas, and demands. Pratt argues that the SDI came about in 1983 because the ABM treaty had denied those with a vested interest in BMD, both within and outside of government, of the one system that had provided a central focus for their efforts. The defense advocates were unhappy with the institutionalization of MAD; the backers of exotic new technologies were looking for a mission that would justify the cost of continued development. The BMD sponsors, who were among the elite network, helped generate demands for new initiatives in American strategic policy by depreciating traditional alternative like arms control while making fantastic claims about their preferred alternatives. This network strategy was unsuccessful until Reagan was elected,
since he was predisposed to technical solutions to problems in general and BMD in particular. The elite network was then able to form a program which forged an alliance of all the BMD sponsors.

There must be both pushers and pullers in this kind of network. The pushers in this case were the weapons sponsors, who stood to benefit monetarily, professionally, and organizationally from BMD. The pullers were the government officials, who publicly proclaim the needs of the state, but who may in fact be simply legitimizing their own interests through the concept of national interest. A Presidential initiative was able to pull these disparate groups into alignment. This "elite network" version of bureaucratic politics theory shows how diverse but compatible interests combine and coordinate to sell favored systems to the government and public.

Defending Newly-Won Bureaucratic Turf: McNamara and the F-111: Robert J. Art has also used the bureaucratic politics paradigm in his study of the development of the F-111 program. He addresses the 1959-1962 period of that system's history, going only to the point where it was determined what kind of aircraft would be built, and who would build it.\(^\text{38}\) Art's study focuses on two basic decisions made by Defense Secretary McNamara: the bi-service decision of September 1961, and the

source selection decision of November 1962.

Art dwells on the fact that the F-111 was the first instance in history where, in the selection of a contractor for an advanced weapons system, the unanimous opinions of the highest military officers of the nation were overruled by a civilian Secretary of Defense. The Air Force Chief of Staff and the Chief of Naval Operations both recommended the selection of Boeing; McNamara and his advisers favored General Dynamics. The difference resulted from the fact that each group of decision makers possessed different criteria for making decisions. Their institutional responsibilities, perspectives, and purposes were different. McNamara changed the rules of the game, and was therefore able to make and enforce a decision even though the military had traditionally been the final authority for selecting sources to develop new weapons systems. He chose General Dynamics over Boeing because its design was more cost-conscious and offered more commonality between the two services. The services were not accustomed to the former, and they did not want the latter. McNamara overruled his military advisers on the source selection as a signal of his intention to strengthen the power of the civilian service secretary in these decisions. His analytic approach to his position, with his coterie of civilian "whiz-kids," reinforced this institutional role. Through systems analysis, he freed himself from dependence on the experience and knowledge of the military officer. Only he
and his small staff had the expertise to do the job according to his redefined criterion, that of cost-effectiveness. He therefore used the contractor selection decision as a tool in his ongoing bureaucratic battle with the service commanders for political power.

The same was true, Art concludes, of the earlier bi-service decision for the F-111. The commander of the Tactical Air Command formed a requirement for something not yet technologically possible: both supersonic dash capability (the ability to sustain treetop-level flight to bomb and avoid radar detection), and a "ferry" mission (spanning the Atlantic Ocean without refueling). This would be the first multimission aircraft, and would require swept wings. This mission requirement was formulated in 1959; in March of 1960 Langley Research Center reported that it had found a way to design a wing so that the center of gravity balance and center of lift could be maintained during wing movement. Whereas the Air Force wanted a high-speed, multimission aircraft, the Navy wanted a single-mission airplane, capable of fleet defense, which involved circling a fleet of ships at high altitudes for long periods. The Navy did not therefore need supersonic capability, but instead endurance. The doctrine of Flexible Response, combined with the desire for cost-effectiveness, led McNamara to decide to pursue the multimission aircraft shared between the services. Both the Air Force and Navy opposed this idea, knowing that limited funds might mean that the
other would jeopardize future programs. They also both knew that the variable sweep wing was technically difficult, and they did not want to burden this effort with the additional difficulties bound to stem from the often conflicting needs of the two services. McNamara thought that the services were using technical unknowns as an excuse for justifying outmoded traditions. He reasoned that technical advances would allow one aircraft to meet the needs of both services adequately. The services wanted to keep their development efforts separate in order to preserve their organizational autonomy. McNamara wanted to unify them to save money, and again, to demonstrate to the services that his decision expertise and authority would determine the outcome of situations like this in the future.

The Effects of Bureaucratic Compromise: The MX: Fen Osler Hampson similarly examines the development of the Trident submarine and missile, the MX and Midgetman ICBM's, the B-1 bomber, the ALCM, the M-1 Abrams tank, and the SDI in light of the bureaucratic politics model. He argues that in the early stages of R&D, a program enjoying strong bureaucratic and political support will get enough seed money to move ahead. As it enters the prototype development and production stage, the program will become increasingly contentious as its political and bureaucratic opponents fight

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to limit the resources it gets. In Hampson's model, bureaucratic and political interests approach weapons acquisition and defense budget issues as non-zero-sum games. Compromise waters down priorities and spreads scarce resources thinly among competing programs. Therefore, costs are inflated, development cycles are delayed and stretched out, programs are changed, and the result is often a weapon that nobody really want. For example, Hampson points out, during the course of the debates over the MX missile, critics wanted to cancel the program, while supporters wanted an invulnerable basing mode to solve the perceived ICBM vulnerability problem. The compromise was to base some MX launchers in Minuteman silos, and some in rail cars. This did not solve the ICBM vulnerability problem, but on the contrary may have made it worse by giving the Soviets a high-value target. The Air Force was also not satisfied; it did not get a large fleet of missiles to improve its own prompt, hard-target counterforce capability.

Getting All the Players on Board: Early and Excessive Requirements-Setting: Thomas McNaugher examines a wide range of weapons systems to construct a bureaucratic model of the entire U.S. weapons acquisition process. McNaugher argues that the requirements-setting process for weapon systems takes place almost entirely in secret within the walls of the

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Department of Defense, and yet a tremendous amount of political activity dominates this early decision making. Since advocates of a weapon system realize that the inevitable cost, technological, and reliability problems inherent in any large-scale weapons development will engender political opposition as soon as the weapon moves into full-scale development and production, the object of the game is to do whatever it takes to build strong, stable coalitions in favor of the weapon as early in the process as possible. This need for rapid consensus building dictates the suppression of alternative technical or tactical solutions to a given mission, the "piling on" of additional (and perhaps unnecessary) technological and performance parameters in order to satisfy a variety of different constituencies, and extremely optimistic cost and performance estimates. As a result, McNaugher argues, the process is forced to tolerate an inordinate amount of risk, and restrictive detail, difficult to change later in the procurement pipeline, is attached to early system requirements. The push for early closure on a single option precludes careful, rational examination of the wisdom of choices being made and of potential alternatives.

Aggressive Program Advocacy and Electoral Politics: Nick Kotz stresses electoral politics in his analysis of the development of the B-1 bomber.41 His central thesis is that

when the President or Congress has denied service requests, uniformed military leaders often aggressively carry their program advocacy into the political arena. They appeal to special interests such as defense contractors, labor unions, and communities where the weapons would be built or based.

Kotz's history of the B-1 is laced with political maneuvering of this sort. Basing decisions for the B-1 were used as political bait, rather than being made according to militarily sound criteria. Defense Secretary Laird and the Joint Chiefs of Staff refused to support SALT I unless the Congress supported the B-1 and Trident programs. During the Nixon re-election campaign of 1972, when Nixon expected California to be crucial, he started a "Keep California Green" program to attack unemployment in the state by promising business to defense contractors located there, including of course support for the B-1. An extensive lobbying coalition was formed by the Air Force and Rockwell that worked the Congress extensively. It persevered under many presidents who opposed the B-1 program over a 30-year period. Its bureaucratic strategy was patience, perseverance, and survival.

At least one analyst, however, has meticulously shown that Kotz's variety of political and bureaucratic advocacy arguments is overblown. Kenneth Mayer demonstrates convincingly, through careful statistical analysis, that explanations of weapon system choices based on "pork barrel"
politics models are simply inaccurate. It is true, he admits, that prime contractors unquestionably distribute subcontracts over as many congressional districts as they can, and that contract awards are timed in synchronization with the electoral cycle to provide maximum political benefit to the legislators who must vote in favor of the programs' continued funding. Mayer finds, however, that weapon systems advocates' attempts to "buy" legislators are generally unsuccessful. "The influence of local spending is small compared to that of other factors -- such as whether members [of Congress] are hawks or doves on defense -- and played no role in determining which side [in any given weapon system debate] won." Congressmen and Senators will fight to preserve a program facing cancellation if a substantial amount of employment in their district depends on it, but their efforts generally fail if the only argument they can make has to do with jobs. "There is, to be sure, a great deal of political activity surrounding defense contracting and spending decisions, but it has little effect on final decisions."}

Desmond Ball puts a slightly different twist on the electoral politics model in his analysis of the strategic

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43 Mayer, p, 99.
missile buildup of the Kennedy administration.\textsuperscript{45} Self-generated pressures, Ball contends, emerged from a 1960 election campaign where promises were made to be "strong on defense." The "missile gap" was a major campaign issue, and Kennedy could not break with his campaign supporters, nor deny the expectations he had generated within Congress, industry, and the military.

Ball then reverts to standard bureaucratic politics theory when explaining the exact numbers of 1000 Minuteman missiles and 41 Polaris submarines. These numbers were arrived upon as a result of complex bargaining, negotiation, and compromise between groups and personalities in and out of government. The services largely wanted higher numbers of weapons, while the White House and the Office of the Secretary of Defense compromised largely over fears of Congressional reaction, not wanting to damage budgetary requests. There was also genuine apprehension in the White House and among Pentagon civilians, Ball claims, of a real "revolt" by the Air Force. That the eventual figure of 1000 was closer to McNamara's original position than the Air Force's reveals his own personal strength and the greater support he was able to muster within the administration.

\textit{The Sources of Weapons Procurement Choices: Predictions from Bureaucratic Politics Models}

II-A: If bureaucratic politics models are dominant, individual personalities or factions will be easily identified with particular technologies and their incorporation into specific weapons systems.

II-B: These personalities and factions will selectively edit and alter the information they pass along to other participants in the weapons procurement process in order to further their own bureaucratic goals.

II-C: The chronological sequence of events will involve significant threat assessments conjured up as rationales to particular weapons systems after bureaucratic factions have attached vested interests in those systems.

II-D: Additional technologies will be added to the weapons system as it makes its way through the procurement pipeline in such a manner as to satisfy various bureaucratic constituencies.

II-E: If the technological imperative model is at work, the victorious bureaucratic players will undoubtedly be the scientists, engineers, and their allies.

II-F: In addition, if the technological imperative model is accurate, weapons systems will be more likely to make their way through the procurement process successfully if the scientists and engineers have substantial political power, influence, or access.

II-G: Weapons system choices will often not be the absolute product of any one bureaucratic constituency's wishes, but instead the political resultant of bargaining among several factions. In other words, the weapon that emerges from the pipeline will be one that satisfies no one completely, but satisfies everyone at least in part.

If bureaucratic politics models are not dominant, these behaviors might be exhibited:

II-H: Bureaucratic coalitions for and against a weapon system will be diffuse and dynamic. It will be difficult to identify strong, stable coalitions with well-defined opinions about and interests in a particular weapon.

II-I: Constituencies who would be expected to benefit from one particular set of choices about the development of a weapon will nevertheless present an accurate and full range of options to each other and to their superiors.
II-J: Weapons that emerge from the procurement pipeline will be "rational" responses to carefully researched and considered threats. No attempts will be made to compromise on weapon systems capabilities in order to satisfy a variety of bureaucratic constituencies.

II-K: If the technological imperative model is not at work, then various potentially useful exciting and useful technologies may exist in laboratories and experimental designs for varying periods of time without being developed into missionized weapons systems. Only when an urgent, relevant threat materializes will these technologies be harnessed.

Organizational Politics

Organizational politics models focus on subunits within the state, in this case military contractors, armed services, design bureaus, governmental agencies, etc., as the appropriate unit of analysis. According to this model, the critical issue is how governments organize to carry out their duties -- what organizations act on an issue, and with what relative influence? How do the goals and procedures of these organizations affect information flows and availabilities, defining choices? How do the goals and procedures of these organizations affect alternative courses of action? How do they affect implementation? Governmental behavior is thought of not as deliberate choice, but as the output of large organizations, and in some cases subunits within them, functioning according to standard patterns of behavior.

At its core, organization theory states that organizations act in the interest of their own survival and

health, which in practice translates into protecting their core missions, budgets, and personnel. In order to accomplish these central aims, organizations avoid uncertainty. They are reluctant to base actions on an estimate of an uncertain future, and therefore develop procedures developed to emphasize short-run feedback. These existing organizational routines, commonly known as standard operating procedures, constitute the range of effective choices open to leaders of organizations, in terms of both inputs and outputs.\footnote{Allison, \textit{Essence of Decision}.} This limited menu reflects not only the cost of generating alternatives, but also each organization's interest in controlling, rather than presenting, choices. Alternatives built into existing organizational goals will be adequate; those not will be poor. Alternatives requiring the coordination of several organizations will also be poor. The same is true of alternatives lying between organizations.\footnote{Allison, \textit{Essence of Decision}, pp. 90-91. See also Barry R. Posen, \textit{The Sources of Military Doctrine: France, Britain, and Germany Between the World Wars}, Cornell University Press, Ithaca, 1984, pp. 45-46; and James Q. Wilson, \textit{Bureaucracy: What Government Agencies Do and Why They Do It}, Basic Books, New York, 1989, pp. 221-222.}

The habit of performing this limited menu of alternatives ingrains values of predictability, stability, and certainty which seem inimical to organizational innovation -- for our purposes, the selection and development of new weapons systems
and weapons technologies. According to organization theory, three major incentives might overcome these factors and permit innovative behaviors to develop: failure, pressure from without, and a desire to expand. Events understood to be failures challenge the organization's basic existence. If an organization owes its existence to the achievement of a certain purpose, it must innovate in a way that so that it can continue to achieve that purpose, or it will suffer. In the case of pressure from without, unsatisfied clients tell the organization what is wrong. If they have formal authority over the organization, they will be able to set innovative processes in motion. In terms of expansion, organizations often wish to expand in order to control environmental uncertainty and to seize new resources that can be used to reward their members. In most cases, however, organizations will choose to protect core missions rather than expand into new ones. The maintenance of core missions or organizational "turf" is paramount, and can be endangered by diluting the organization's resources and attention toward expansion out from the "core."

One subset of organization theory, resource dependency theory, focuses on the ways that organizations respond to

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49 Allison, p. 85; Cyert and March, p. 285.
50 Posen, p. 46.
pressure from without, seeking to manage or strategically adapt to their environments. Subsequent to organizations are not internally self-sufficient, they require resources from the outside. Thus organizations develop dependencies on components of their environments, which vary with the degree of need (for a raw material, for instance) and the number of alternative sources of supply. Dependence and power relative to various environmental components are therefore inversely related. Resource dependency theory suggests that organizational behavior becomes externally controlled to the extent that the focal organization must attend to the demands of those in its environment that provide resources necessary and important to its continued survival.

A major facet of resource dependency research deals with the conditions under which an organization will comply with

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54 For discussions of related ideas in the area of control theory, which asserts that greater control, the capacity of an organization to manipulate available means for the satisfaction of needs, yields greater organizational effectiveness, and vice versa, see Arnold S. Tannenbaum, Control in Organizations, McGraw Hill, New York, 1968; and Tannenbaum and Robert A. Cooke, "Organizational Control: A Review of Studies Employing the Control Graph Method," in C. J. Lammers and D. Hickson, eds., Organizations Alike and Unlike, Routledge and Kegan Paul, London, 1979.
external control attempts. In such instances, the degree of compliance is a function of the importance of the resource that is needed and the extent to which an external actor has discretion and control over access to that resource. Dependence is also increased to the extent that control over the resource is concentrated in relatively few hands. One study, for example, examined the expressed willingness of Israeli managers to comply with various government requests, such as investing in development areas and foregoing local profits to engage in export activity. It found that dependence on the government, whether because of sales to it, dependence on it for financing, or dependence on it for legitimacy because of high percentage of foreign ownership, tended to be associated with compliance to governmental policies.

According to the resource dependence perspective, however, organizations do not merely respond to external constraint and control through compliance to environmental demands. A variety of strategies may also be undertaken to

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55 Pfeffer and Salancik, 1978, p. 44.


alter the situation confronting the organization to make compliance less necessary. These strategies might include competition, a rivalry between two or more organizations for the exchange of goods and services; co-optation, absorbing outsiders into the policymaking structure of the organization to avert threats; and coalition, combining organizations for a common purpose. Organizations in an uncomfortably dependent position will also strive to create conditions of self-sufficiency, sealing off their functions from environmental influences and approximating closed system conditions to the greatest possible degree.

Organization Theory: Military Services and Mission Orientation

Many analysts have argued that the military services are particularly stark examples of the core tenets of organization theory because of their propensity to protect their traditional missions and organizational interests. Perry McCoy Smith provides a prime example of this phenomenon in his


59 Thompson, 1967.
work on the origins of the United States Air Force. He argues that the post-war planning done by the air staff of the army was entirely oriented toward making the case for organizational autonomy for the Air Force. Other factors, including doctrine, base requirements, and weapons system forecasts, were secondary considerations which could be modified in the interest of strengthening the Army Air Force aim of independence. The post-war planning for organizational independence was therefore thorough, detailed, and well-conceived, while that for international contingencies suffered from concentration on the organizational aspects of the post-war military structure. The post-war world situation and potential threats to American security were of lesser concern than the issue of how the Army Air Force could justify its case for autonomy in the post-war period.

Organizational conservatism and uncertainty avoidance is also reflected in the armed services' tendency to develop fairly fixed views of their missions and the mainstream types of weapon systems that they prefer. Their views are shaped largely by national historical experiences and service traditions. This service conservatism and rigidity to change, coupled with the competitive impulses driving weapons developers, results in what Mary Kaldor has coined the

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"baroque arsenal."\textsuperscript{61} On one side of the equation, the services conceive of progress as improving existing capabilities and resist innovations which do not correspond to their existing organizational structures. Each military unit is associated with a specific mission, and new technologies may challenge the utility of that mission and hence pose a risk to organizational survival. For example, the Air Force is committed to manned fighter aircraft. It is disconcerting for the Air Force to realize that remotely piloted vehicles might fulfill the functions of manned aircraft more efficiently, and hence it does not pursue such technical options with vigor.\textsuperscript{62} The military wants sophisticated technology only when that technology is consistent with its preferred tasks.

Paradoxically, the institutions supplying the weapons to the conservative military services -- the defense contractors -- are themselves quite conceptually and technologically innovative. They are concerned with continuous development and production to ensure the employment of capacity. They must therefore obtain new orders once the development of the old systems is completed. This generates intense technological competition between main contractors.


\textsuperscript{62} R. James Woolsey, "The Sources of Technological Innovation," Feldman, pp. 21-22.
The dynamic impulse emanating from this contractor competition is constrained by the organizational rigidity of the armed services. New technology can only get through the innovation and integration stages if it conforms to the requirements of the dominant service mission. Hardware may be radically innovative, as long as it is directed toward improving the performance of missions defined and established forty years ago, currently defined by sets of performance parameters like speed, payload, and protection. It is this dynamic yet conservative form of technical change that is known as "baroque." Only the exigencies of battle can compel institutional change, giving rise to truly revolutionary technologies that challenge the organization of users and producers. For example, smart weapons and new area destruction munitions originated in Vietnam and the Middle East.63

Application of Organizational Models to Weapon System Choices

Managing Uncertainty: The Cybernetic Paradigm and the F-111: Robert Coulam has described the acquisition of the F-111 aircraft in terms of a cybernetic decision model, which he develops as a modification of the rational actor model. His application of the model to the F-111 case, however, winds up accurately explaining the uncertainty-avoidance behavior of

63 Kaldor, in Feldman, pp. 113-116.
organizations. According to the rational actor model, he says, decisions are made which maximize the given goals of the individual or organization. For each decision, a number of alternatives are conceived, with consideration of the probable outcomes of each; relevant goals are integrated as an intrinsic part of the process; the process seeks out and responds to new information; and the alternative chosen will be the one with the highest probable net payoff in terms of the decision-maker's goals. For a collective decision, this requires that the calculations be explicit and observable, and that they be shared by the actors involved.

Coulam's modification of the rational actor model, the cybernetic paradigm, states that decision-makers act "rationally" but on the basis of a simplified image of complex problems, oblivious to the results of their efforts except insofar as the simplifications are implicated. A servomechanism governs behavior; there are no output calculations. Only a few feedback variables are tracked, with the decision maker reacting solely to variations in this select information. The decision maker is therefore essentially blind to his environment. His repertory of sequential operations produces an outcome as a result of completing the sequence, but the outcome is not conceptualized in advance.

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According to Coulam, this must be the way decision processes work because human thought and memory is structured. If new information challenges the existing structure of beliefs, human cognitive processing mechanisms work unconsciously to restore the disturbed consistency. A decision maker craves simplicity and stability. Under conditions of uncertainty, the cognitive criterion of consistency forces a mental dissolution of the tradeoff. The decision maker will conceptualize the world in such a way that the values do not seem to conflict. Favorable outcomes will be inferred for preferred alternatives, and unfavorable outcomes will be predicted for alternatives the decision maker intends to reject. A cybernetic decision maker will screen out information which his established set of responses is not programmed to accept.

The cybernetic paradigm can also govern the behavior of an organization. The organization regiments the belief structures of the individual who comprise it. Top management focuses in sequential order on decision issues raised by separate subunits and does not integrate across subunits in its deliberations. Decisions are made wholly within the context of the subunit raising the issue. Complex problems are fragmented according to subunit organization. The decision process for each subunit then operates as described by the cybernetic paradigm. Decision makers avoid uncertainty and do not attempt to calculate outcomes. They monitor
relatively few feedback channels, and discover the effects of their actions only insofar as they register on the feedback variables. Decision problems result from unacceptable variations in feedback. When unacceptable feedback is received, the subunit will start a restricted search process, which reveals options first in the area of marginal adjustments to the alternative already in use, then in the area of the next, pre-programmed item in the response repertory. As these options are applied, new feedback information is generated. Once new information represents a return to acceptable levels, the search process will end. In short, there will be a relatively closed cycle of categorical and short-range responses to unfavorable feedback variation, with little higher-order calculation to be expected. Even when problems are foreshadowed by considerable information, a subunit will not necessarily act to forestall them. It will act only when the information registers on feedback variables to which it is attuned. Coulam applies this model to the development of the F-111 aircraft, asking several questions that did not seem to be answered by the rational actor paradigm. For the Air Force version of the plane, why was a nuclear bomber developed to fulfill limited war missions? Why was this initial commitment to the Air Force's specifications sustained throughout the development? Why were 141 Air Force F-111's produced with relatively restrictive air inlets and a permanent susceptibility to engine stalls? For the Navy
version, why did the aircraft gain weight during the course of development? Why were Navy pleas for redesign never accepted? Why was the Navy's version cancelled?

Coulam claims that the underlying influence of cognitive simplification and organizational routine was decisive. Defense Secretary McNamara and his associates were insensitive to the inevitable complexities of a biservice program, and were in no position to control the vast apparatus that implemented their directives. Throughout the program, the decision makers acted on the basis of simplified images of emergent problems. Their perceptions conformed to their pre-existing requirements and schedules; they avoided the implications of information threatening to these images. The initial development plans for the aircraft decisively structured the efforts that followed. Within that structure, the development process proceeded smoothly. Predictions of development problems, such as the early anticipation of weight and compatibility problems, went unrecognized. Even when the actual emergence of problems directed technical attention toward them, only remedial efforts were instituted, while development or production proceeded apace. No one undertook the aggressive initiatives necessary to the program's success.

Escaping Political Games: The Creation of Independent Organizations: The most frequent use of organizational politics models in explaining weapons procurement seems to be
to show that the most successful weapons programs are those which escape the ravages of bureaucratic and organizational politics through the creation of separate organizations apart from the rest of the procurement bureaucracy. Gerald Steinberg, for example, points out that, over time, bureaucratic and organizational factors became increasingly important in sustaining the Strategic Defense Initiative.65 By creating an independent organization for the SDI within the Department of Defense, the program was provided with a bureaucratic base from which to increase its budget and power in the decision-making process. The SDIO's independence from services, defense agencies, and DDR&E was an organizational framework intended to streamline the management process and accelerate the pace of research. It brought together related projects previously spread among several defense agencies and bureaus.

The implications of this structure were many. The SDI program had more bureaucratic bargaining power, since it no longer had to compete with other R&D projects directly in the DDR&E structure, but instead had achieved a special organizational status. The SDI was also taken out of the DSARC milestone authorization structure. All SDI projects were reclassified as advanced development projects, skipping the necessity of proving within the DSARC framework that the

technical foundation exists to support system development. Industrial lobbies were also given an organization around which they could coalesce.

Harvey Sapolsky similarly examines the evolution of the Fleet Ballistic Missile program, including the Polaris missile, its attendant subsystems, and the force of 41 nuclear-powered submarines.66 His study describes the success of the Special projects Office of the Department of the Navy, which managed the program.

According to Sapolsky's account, in the mid-1950's, inter-service rivalry sprung up over the prospect that missile units were soon to be a significant part of the strategic force. The Navy was the last service to propose a ballistic missile program, and the first to feel the effect of the Eisenhower budget reduction policies. Jurisdictional disputes, conflicting technical advice, and lingering concern about the use of nuclear weapons delayed the formation of a united front in the Navy over establishing a ballistic missile program. At first the Navy was forced to join the Army in modifying the Jupiter missile for use on ships and subs, but eventually it was able to argue successfully that the liquid-fueled Jupiter would not be safe on a submarine, and that it would therefore be both cheaper and safer to produce an all-new solid-fueled missile than to modify the Jupiter.

In December of 1956, the Navy was given the authority to start the Polaris program. The program was an outstanding success, with no hint of cost overruns, and deployment taking place several years ahead of schedule. This success stemmed from the skill of its proponents in bureaucratic politics, and most of all from its organizational autonomy. The Fleet Ballistic Missile Office had the resources and authority to control independently the design, construction, and maintenance of the force. The FBM Office had two objectives to this end: to attract a broad base of support for Polaris in and out of the Navy, and to prevent the rest of the Navy and government from interfering in the management of the program.

According to Sapolsky, these objectives were accomplished with four strategies. The first was differentiation, by which the FBM office established unchallengeable claims on valued resources by distinguishing its product or program from those of competitors. The argument for retaliatory survivability made this task relatively easy. Second, the FBM office pursued a strategy of cooptation. Potential critics were drawn into the program and implicated in its activities. There was a genuine sharing of decision power with the defense contractors, on whom the FBM office relied for the bulk of its R&D and management support, as well as for procurement. Third, the FBM office adopted a policy of moderation. It built long-term support by sacrificing short-term gains. Restraint was necessary to avoid creating animosity. For
example, an elite status was not established for FBM submarine crews, as this would have alienated the rest of the underwater Navy. Finally, the FBM office adopted managerial innovation with the PERT, or Program Evaluation and Review Technique, to minimize the degree to which it had to justify and review in detail each decision. Through these four procurement sub-strategies, the FBM office was guaranteed the organizational autonomy it required to run a successful program.

**Organizational Resistance to New Ideas and Missions:** Edmund Beard has taken another angle on the organizational politics model to explain the development of the ICBM, focusing on the fact that services are unwilling to pursue technical options which do not fit into their narrowly-defined missions. He describes the history of the ICBM as a decade-long pattern of nondecisions, characterized by inaction, procrastination, selective ignorance, and unwillingness to recognize new facts. Organizational vested interests and the associated technological conservatism blinded the relevant actors to what might be obvious or rational in retrospect.

According to Beard, the Air Force vehemently resisted the ICBM program in the late 1940's and early 1950's because of a cultural and institutional commitment to manned aircraft. From 1949-1954, a variety of arguments were used against ballistic missiles, primarily that the technology was not

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available, and that there was no relevant threat or military requirement. Contrary evidence to each of these claims was increasingly available during that period, but the Air Force devoted little time or money to ballistic missile research during this period, and hence few results were achieved. Throughout this period, Beard relates, the Air Force displayed an interest in ballistic missiles only if it seemed that the Army or Navy might want them. The result of the ensuing organizational battle was that the Air Force "won" responsibility for ballistic missiles, and then proceeded to ignore them. It supported the Snark, the least efficient of the contemplated long-range missiles. While a great deal of money had been invested in the Snark program, it lacked accuracy and reliability and never obtained operational capability. Beard speculates that Snark may have been supported in some quarters precisely because it did not constitute a real threat to the B-52 or any follow-on bomber. During the same period, however, the Air Force did indeed invest a great deal of effort into the development of standoff missiles, which were considered vital to the health and effectiveness of the manned bomber fleet. Beard's work then goes on to demonstrate the same phenomenon as Steinberg and Sapolsky: a revolutionary new weapon will be organizationally stifled by outdated doctrine or methods if it is not assigned an independent agency to foster it. The Western Development Division was created in 1954 to take responsibility for
ballistic missile development because there was fear that the BM program would be delayed or even sabotaged if it was left to the normal operations of the Air Force. Once that structure took hold, the ballistic missile program was successfully developed, and the BM fleet gave birth to an independent Air Force subculture.

Art and Ockenden's analysis of cruise missile development takes a similar organizational perspective. They observe that, just as the Air Force did not want ballistic missiles decades before, the military services did not want the cruise missile, since it threatened their respective dominant missions or ate into scarce funds. The ALCM was rammed down the throat of the Air Force; the Army refused to accept responsibility for the GLCM. The Air Force stuck with it, but gave it no priority. Similarly, the Navy did not want the SLCM because it threatened carrier-based aircraft.

Only the intervention and support of high levels in the Pentagon, the White House, and the State Department forced cruise missile development to proceed so fast and so far. Driven by the SALT I and II negotiations, the NATO allies' concern over the reliability of the United States nuclear umbrella, and White House anticipation of adverse Congressional action on SALT II if cruise missile technology

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were not developed to the fullest, civilian intervention forced action on the weapons system. According to Art and Ockenden, at every crucial stage of the development of each type of cruise missile, high-level political intervention was necessary to start or sustain it.

**Strengthening Old Ideas and Missions:** Graham Allison looks at the development of the multiple independently-targeted re-entry vehicle also as a product of organizational and bureaucratic politics, showing how a weapons system will quickly and efficiently take its place in the arsenal if it responds to the interests of the players involved. He clearly demonstrates the convergence and alliance of interests in favor of MIRV’s. For the Air Force, MIRV’s contributed to their central mission, fighting strategic wars, and special interest within that mission, the destruction of time-urgent military targets. For the Navy, it enhanced their ability for assured destruction of countervalue targets. The Navy also had to support MIRVing to maintain equal status in their competition with the Air Force. For the technologists, the weapon was technologically sweet, and even better, it worked. For the Pentagon, it wrapped in a single package a high-confidence assured destruction capability against almost any conceivable Soviet threat (including anti-ballistic missile threats), increased counterforce, targeting flexibility,

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ammunition in the battle with the Air Force to hold down the number of Minutemen and avoid new manned bombers, a defense against critics saying that the Soviet Union was gaining strategic superiority, and an argument against American ABM (that the Soviet Union would simply MIRV and overwhelm it).

Michael Armacost's work analyzes the development of the first intermediate range ballistic missiles, also stressing both organizational and bureaucratic politics. In 1955, he relates, both the Air Force's Thor and the Army's Jupiter advanced plausible and promising technical proposals. From the government's point of view, the exploration of parallel development programs through the development stage offered a means of keeping the future open, technology fluid and up to date, and resources free from the heavier costs of quantity production until a choice could be reached. A spirited competition was therefore nourished between the Air Force and the Army.

As Armacost points out, the development and deployment of Jupiters promised the Army the opportunity to express a variety of grievances against the Air Force, the prospect of enhancing its budgetary prospects, a means of expanding operational responsibilities, an occasion for exploitation of long-neglected technical resources, and a chance to reinforce its capability for fighting limited nuclear war as well as a

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slight possibility of obtaining responsibilities for the exploration of outer space. The Air Force, on the other hand, resisted encroachments on its established roles and missions, and resisted the dilution of the priority previously granted to their development program for the Atlas ICBM. Organizational interests clearly shaped the services' approaches to development and potential deployment of this weapon system.

The Sources of Weapons Procurement Choices: Predictions from Organization Theory

III-A: The organizations involved in weapons procurement -- the Department of Defense, the armed services, Congressmen, and contractors -- will minimize uncertainty in their environments by practicing routine behaviors.

III-B: These behaviors will manifest themselves in the protection of well-defined core missions and programs.

III-C: The more an actor (scientist, firm, or government agency) in the weapons procurement process controls scarce resources (material, intellectual, or informational), the more control he will have over weapons system choices and outcomes.

III-D: The degree of power accruing from the holding of scarce resources will vary inversely with the number of alternative suppliers of those resources. Organizations will adapt to make compliance with the wishes of holders of scarce resources less necessary, pursuing strategies of cooperation, co-optation, and/or competition.

III-E: The standard operating procedures of organizations involved in weapons procurement will inhibit innovative behavior. In other words, unless spurred on by failure, pressure from without, or a desire to expand, military services will strive to maintain the status quo in terms of
missions and technologies.

III-F: In particular, military services will resist weapons systems and technological innovations which are not specific to their established missions. They will, however, strive for ever-increasing technical capabilities along a narrow set of traditional mission parameters, and will fight to maintain those missions they deem essential for their organizational survival.

If organizational politics models are not dominant, these behaviors might be exhibited:

III-G: Organizations will respond in different ways to different situations. Uncertainty will be treated as a welcome challenge, in response to which the organization will find new ways to behave under new circumstances.

III-H: Resources will be newly distributed among organizations each time a challenge arises in order to maximize the effectiveness of the overall response to the problem.

III-I: Military organizations will, in response to carefully considered and perceived threats, innovate independently and without prodding to create appropriate new mission definitions and technologies.

Alternate Approaches

A limited subset of the weapons procurement literature has gone beyond the either-or approach to the use of the levels of analysis as analytic tools. This synthetic work sprung from the realization that, as Harvey Sapolsky has observed, "a complete understanding of the weapon acquisition process, it would seem, will require an amalgamation of the various perspectives."\(^7\)

Jonathan Stein, in exploring the issue of whether policy drives technology, or vice versa, concludes that bureaucratic politics provides the determining and sustaining impetus to weapons programs involving genuinely new and revolutionary technologies, but that for incremental technical innovations, technology is likely to drive policy.\textsuperscript{72} He then examines the development of the hydrogen bomb and the Strategic Defense Initiative in detail, showing that these revolutionary technologies were indeed fostered by sharp political impetus. The H-Bomb program was begun because of a January 1950 directive from President Truman; similarly, the SDI was propelled by a March 1983 decree from President Reagan. He does not, however, examine any cases of incremental innovation to test the other side of his hypothesis.

Ted Greenwood's study of MIRV development explicitly examines the gamut of hypotheses outlined earlier in this chapter, and concludes similarly that single-factor explanations leave the reader with an unsatisfied appetite.\textsuperscript{73} He states that a general predictive theory is not possible for the subject of weapons procurement, and that the tasks of the analyst of the historical case study can only be as follows: to bare the inner workings of the decision process, identifying various strands to show how they converge and


diverge, overlap, and intermingle to produce the observed outcomes, in other words, to sensitize the reader to the large range of relevant variables; and to suggest some generalizable propositions about the interrelations of these variables.

Greenwood's propositions, along those lines, are the following. First, a weapon needs political support from controllers of needed resources and from most sources of potential opposition. In the case of the MIRV, what little opposition existed appeared late in the program, and never had a significant political base. Second, the technical community can limit the range of options presented to policy makers. By initiating exploratory development of a new weapon system and subsystems, and through its own allocation of effort and resources, the technical community both structures and significantly reduces the choices of the services and civilian decision makers. The technical community and DDR&E were a major source of inputs to McNamara on MIRV decisions, and they had a distinctly pro-technology bias, limiting the range of options McNamara was presented. The Office of Systems Analysis had no authority over systems not yet programmed for deployment; if it had, it might have defined options more broadly. Third, however, top policy makers' individual preferences are also important. McNamara's fear of the Soviet ballistic missile defense threat led him to authorize MIRV engineering development in the FY 1966 budget. Fourth, once a system is far enough advanced, it is likely to have
accumulated enough personal and organizational interest that it will be difficult to stop. This was true of MIRV by the time it entered engineering development. Finally, strategic preferences form part of the belief structures of relevant actors. The MIRV was accepted so readily because its deployment could advance so many different approaches to nuclear strategy that almost everyone came to see it as fulfilling his preferences.

Matthew Evangelista goes beyond a list of general propositions to accomplish what Greenwood a decade earlier had said was impossible. He constructs a comprehensive, cross-national theory of decision making and technological innovation in weapons procurement. He argues that, by looking at the state-society relationships within the United States and the Soviet Union, it is possible to determine whether and when external determinants and internal determinants will offer more explanatory power. The United States, a weak state with a strong society borne of its early industrialization, has developed strong, autonomous bureaucracies and interest groups, and therefore should overall be more responsive to internal pressures. The Soviet Union, on the other hand, with its strong state and weak society, borne of late industrialization under intense international pressure, should exhibit greater sensitivity and

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responsiveness to external stimuli. He then goes on to characterize five parallel stages, based on this state-society relationship, for the American and Soviet weapons acquisition processes, which explain and predict which factors will have the most influence at which stage of the procurement process. In the United States, the stages are: (1) technocratic initiative, where scientists discover new ideas and advocate military applications for them; (2) consensus building, where scientists and their military associates generate interest in the new technology within the military-technical community. This stage is also characterized by the inability to limit technical options; goldplating must satisfy nearly everyone; (3) promotion, where scientific, military, and industrial "entrepreneurs" promote new weapons within the military services, Congress, and the Executive branch. Interservice rivalry is often evident at this stage; (4) open windows, where external threats serve as windows of opportunity for the military to push a new weapon into production; and (5) high-level endorsement, where Pentagon officials gain Congressional support for mass production of a new weapons, justified with more specific reference to an external threat. In the American model, therefore, the internal factors are decisive in creating the innovation, and external factors merely play catalyzing or justifying roles much later in the procurement process.

The Soviet process contrasts greatly: (1) stifled
initiative, where there are limited technical antecedents, some discussion of possibilities, but innovation is constrained by established priorities; (2) preparatory measures, in which low-level efforts prepare broad technical background but continue to yield to higher-priority programs; (3) high-level response, where a directed response to a foreign initiative begins a reassessment of priorities at the top; (4) mobilization, where the leadership endorses an all-out effort to pursue the innovation as the nature of the new priorities becomes evident. At this stage, allies are also found in the military to support the new program; and (5) mass production, where the mass production of the new weapons coincides with the implementation of new strategic priorities, often publicly announced at the highest levels. In the Soviet case, in sum, the political environment does not permit internal factors to play a role early in the process, and therefore high-level initiative, prompted by external factors, is the real force behind technical innovation. Evangelista goes on to apply this framework to the case study of the development of tactical nuclear weapons.

Michael Brown’s work on the development of U.S. strategic bombers in the post-war period also takes into account the dynamic interaction between the levels of analysis. First, Brown makes it clear that he will examine only weapon systems

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which fall within established mission areas, explicitly taking into account Stein's thesis that revolutionary programs may exhibit qualitatively different dynamics than evolutionary programs within established mission parameters. He then goes on to conclude that U.S. bomber programs have, as a rule, been initiated by military services in response to either strategic or bureaucratic threats. Strategic threats, Brown argues, emanate from a sense that new developments in the international system have rendered existing bomber systems obsolete, requiring new designs. Bureaucratic forces usually have to do with the Air Force's need to "sell" its new programs to civilians in the executive branch and to Congress. In order to respond to both kinds of impetus, the Air Force has invariably set extremely high technological and performance parameters for its new bombers -- high enough to counter worst-case scenarios about what weapons the Soviet Union might be capable of fielding in the future, and high enough to ensure that all bureaucratic constituencies would be convinced of the need for the new capability and hence sign on to it.

Brown also asks questions about what constitutes procurement success. He finds the answers to lie in the combination of ambitiousness of the development objectives (does the new weapon system demand substantial advances in technology and performance?) and procurement strategy (the degree to which development and production of the weapon occur
simultaneously during the procurement process). Brown argues persuasively that a high degree of concurrency is appropriate for systems which incorporate only modest advances in technological sophistication, but that the risks involved in the pursuit of unknown technologies dictate a more sequential procurement strategy for weapon systems of that type. Combinations of high concurrency and leaps in technology are prohibitively risky; on the other side of the coin, combinations of low concurrency and known technology are wasteful.

With these conclusions in mind, Brown observes that the strategic and bureaucratic pressures which are responsible for the genesis of new strategic bombers also tend to lead the Air Force and weapons designers toward high levels of concurrency and the development of new and unfamiliar technologies. Concurrency seems to promise cost savings, more rapid fielding of weapons desperately needed to counter a looming threat, and insurance that the weapon will not be cancelled, since it is difficult for Congress to axe a system once substantial resources have been invested early in the production process. Unfortunately, since a high level of concurrency is inappropriate for the ambitious development objectives being pursued, the result frequently is procurement disaster.

Richard Hallion, in his work on United States Air Force fighter aircraft acquisition in the post-war period, similarly addresses issues of procurement success versus procurement
failure. He explicitly recognizes the different levels of analysis inherent in sophisticated explanations of weapon system choices in his statement that "aircraft acquisition is inextricably caught up in the interplay and tension between doctrine and operational thought (the requirements pull) on one hand and technology (the technology push) on the other." Hallion argues that successful aircraft design and procurement strategies will recognize the need to respond to both kinds of influences -- "insightful appreciation of how warfare is likely to evolve, and what contemporary and future technology could realistically offer."  

A Comprehensive Approach: The New Institutionalism

A body of theoretical literature has recently emerged to assist analysts struggling to understand how different types of causal factors interact to produce state behaviors -- in this case, weapons procurement outcomes. That literature, known as "the new institutionalism," recognizes explicitly the importance of national institutions, institutional configurations, and the norms and ideas which influence them, in shaping the way that various kinds of stimuli affect

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77 Hallion, 1990, p. 4.

78 Hallion, 1990, p. 20.
policy-making processes. In sum, institutions are not necessarily conceived of as unique independent variables; they do not cause policy outcomes. Instead, they act as prisms through which all kinds of factors -- strategic inputs from the international system, and domestic-level inputs from bureaucratic politics, organizational politics, and technology -- affect policy choices.

First of all, institutions are recognized as political actors in their own right. "The bureaucratic agency, the legislative committee, and the appellate court are arenas for contending forces, but they are also collections of standard operating procedures and structures that define and defend interests...The claim of [institutional] coherence is necessary to treat institutions as decision makers." 79

As such, institutions can perform many functions. They can affect political resource distribution, which in turn affects the power of political actors. "Wealth, social standing, reputation for power, knowledge of alternatives, and attention are not easily described as exogenous to the political process and political institutions." 80 As Peter Hall points out, the institutional organization of policy-making also influences political actors' definitions of their own interests, through the establishment of their


80 March and Olsen, 1984, p. 739.
institutional responsibilities and their relationship to other actors. "In this way, organizational factors affect both the degree of pressure an actor can bring to bear on policy and the likely direction of that pressure. Such an analysis can be applied both inside and outside the state." In other words, not only the strategies, but the goals which political actors pursue are shaped by their institutional context. Simply stating that political actors act strategically to achieve their own ends does not tell the whole story; institutional analysis reveals what they are trying to maximize and why they stress certain goals over others.

Institutional structures can also influence the capacities of government officials and other political actors to carry out policy. An appropriate, or minimum adequate, set of institutional mechanisms and policy tools is necessary in order for a given policy to be implemented. "The policy alternatives of leaders are not defined completely by exogenous forces, but are shaped by existing administrative


agencies."  

The lion's share of early and current institutionalist work concentrates on formal institutions -- constitutions, formal political practices, etc. The approach examined here casts a broader net, following Peter Hall's example to include consideration of the role of institutions located within national societies and national economies, as well as less formal organizational networks, in the determination of policy. Particularly since the formal institutions in the three countries being examined here, the United States, former Soviet Union, and Japan, are quite different, the flexibility of this more expansive and less rigid approach permits cross-national comparison.

As mentioned above, institutions are conceived here as prisms. The set of institutional capacities and relationships in any given polity, regarding any given issue area, can act to structure the role of pressures from both societal groups and the international arena. Institutions "constrain and


85 See, for example, R. Kent Weaver and Bert A. Rockman, eds., Do Institutions Matter? Government Capabilities in the United States and Abroad, Washington, D.C., The Brookings Institution, 1993; and much of the work by March and Olsen.

86 Hall, p. 20.

87 Ikenberry, p. 236.
refract" politics, but are not the primary determinants of policy outcomes. "Institutional analyses do not deny the broad political forces that animate various theories of politics.... Instead, they point to the ways that institutions structure these battles and in so doing, influence their outcomes." In other words, an institutional focus permits the analyst to take into consideration all the levels of analysis described in detail earlier in this chapter: international system dynamics, bureaucratic politics, organizational dynamics, and the imperative of technological progress. The institutional approach acknowledges that all of these factors play a role to some extent and under certain conditions. It therefore abandons the search for a grand, unified theory to explain policy outcomes, and instead focuses on institutional structures and processes with a middle-range, "path-dependent" perspective, hypothesizing that all other types of inputs must flow through institutional structures before they can affect policy outcomes. We can therefore focus on these institutional variables as a means for understanding how various types of explanations relate to one another; institutionalism gives us a tool with which we can search for generalizable patterns of behavior. It helps us to understand policy continuities over time within countries and policy variation across countries. It structures our explanation of political phenomena by providing a perspective

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88 Thelen and Steinmo, p. 3.
for identifying how different variables relate to one another. The stress is on "intermediate institutions that shape political strategies, the ways institutions structure relations of power among contending groups in society, and especially the focus on the process of politics and policy-making within given institutional parameters."^89

[Institutionalism] demonstrates the relationships and interactions among a variety of variables in a way that reflects the complexity of real political situations... By placing the structuring factors at the center of the analysis, an institutional approach allows the theorist to capture the complexity of real political situations, but not at the expense of theoretical clarity. One of the great attractions and strengths of this approach is in how it strikes this balance between necessary complexity and theoretical clarity.^90

It is important, in association with the use of institutionalism as a mid-range theoretical framework for understanding state behavior, to remember that political actors "associate certain actions with certain situations through rules of appropriateness."^91 These rules of appropriateness, or norms, define acceptable behavior for a particular actor in a particular situation, and are defined by the political and social system and transmitted through socialization. These norms are embedded in historical experiences that accumulate over generations of individual experience; eventually, the information about that experience

^89 Thelen and Steinmo, p. 7.

^90 Thelen and Steinmo, p. 13.

is encoded into institutional rules and structures. National institutions, in other words, are not only arenas for contending social and political forces; they are also collections of standard operating procedures and structures that define and defend values and norms.\textsuperscript{92}

The most useful recent work on the interrelationship between norms and institutions has focused on explanations of Japan's national security policy. Peter Katzenstein and Nobuo Okawara, for example, have argued that Japan's national security policies in the post-war period have been influenced by two sets of factors: the structure of the Japanese state, broadly conceived, and the incentives that structure provides; and the context of Japan's legal and social norms, which help Japan to define its policy interests and its standards of appropriateness for specific policy outcomes.\textsuperscript{93}

More specifically, according to Katzenstein and Okawara, the institutional structure of the Japanese state explains the comprehensive character of Japan's national security policy. That structure "biases policy strongly against a forceful articulation of military security objectives and accords pride of place instead to a comprehensive definition of security that centers on economic and political dimensions of national


security." The Ministries of Foreign Affairs (MFA), International Trade and Industry (MITI), and Finance (MOF), have penetrated the Japan Defense Agency (JDA) to a substantial degree and in a variety of ways, the JDA is relatively isolated from the public, and government-business relations are in agreement on questions of raw materials security and weapons procurement policy, adding up to an institutional structure that subordinates military to economic and political security concerns.

The authors explain that institutions alone, however, cannot account for the mixture of flexibility and rigidity which has characterized Japan’s process of adaption to change in its national security environment. In addition, the legal and social norms which have defined and governed Japan’s policy interests must be considered. Katzenstein and Okawara conclude that Japan’s relative policy flexibility on questions of economic security results from a set of norms related to economic security that are largely consensual; few in Japan question the goals of increasing technological autonomy and reducing economic vulnerability. On the other hand, Japan’s relative rigidity when it comes to questions of military security stems from its deeply contested norms in that area; there is much debate in Japan over the legitimacy of the Self-Defense Forces, the constitutional limit on defense spending, and the non-nuclear principles. Finally, the mixture of

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94 Katzenstein and Okawara, p. 21.
rigidity and flexibility in matters of political security has to do with the mixed degree of consensus within Japan over the relevant national norms. Sometimes these norms favor flexibility in policy adjustment, and sometimes they mitigate against it; the pattern varies from issue to issue.

Richard J. Samuels' work on Japan's national security policy pays more explicit attention to the historical interplay between norms and institutions. 95 He postulates that norms, in this case having to do with the way technology is understood strategically and the role it plays ideologically, have been instrumental in shaping Japan's institutional development. National systems are more than aggregate expressions of domestic institutions and sectoral networks. They comprise shared values and beliefs that are confirmed and reconfirmed by the intimacy of shared national experience." 96

Samuels proceeds by defining three central norms that have defined Japan's comprehensive approach to national technology policy and national security policy, and by extension, its national institutions: autonomy, the identification and acquisition of foreign products and manufacturing/design processes in order to stimulate local development; diffusion, the distribution of this know-how

96 Samuels, p. 330.
throughout the economy; and the nurturance of the capacity to innovate and manufacture. This "bundle" of beliefs and practices, these norms, add up to comprise the Japanese ideology of technonationalism.

Like all ideologies, [technonationalism] is a force that precedes and informs the institutions of an entire national economy as well as strategies for national security. Institutions are more than formal organizations in this context, of course, and in particular they include the network of protocols -- the rules and practices that guide and constrain social, political, and economic choice.\textsuperscript{97}

Samuels then describes in detail how the norms of autonomy, diffusion, and nurturance are reflected in Japan's institutional structure. Autonomy is furthered through institutional processes that subordinate profits, costs, and military rationale in weapon systems development to learning and the enhancement of domestic technological capabilities. Paradoxically, where domestic technologies fall behind, Japan has found it necessary to augment its own capabilities through international cooperation. Diffusion takes place through an extensive network of what Samuels calls "technology highways,"\textsuperscript{98} where technology is considered a quasi-public good and little distinction is made between military and civilian technologies. Nurturance is fostered through "an elaborate system of protocols -- sometimes tacit, at other times explicit -- to induce domestic firms, even as they

\textsuperscript{97} Samuels, p. 31.

\textsuperscript{98} Samuels, p. 49.
compete, to negotiate constantly with their competitors and with bureaucrats to share market jurisdiction and control." In sum, the relationships between these norms and the institutions they engender explain Japan's comprehensive approach to technology and technology's place in national security policy.

James Kurth makes a technonational argument with regard to the United States in his well-known statement of the "follow-on imperative." Through time-series analysis of the relationship between post-war U.S. military and military-related aerospace systems, and the aerospace corporations which produce those systems, Kurth demonstrates that the U.S. government has treated large, established aerospace production lines as national resources that cannot be allowed to wither. Charting the years when major contracts have been awarded together with the years in which major production lines were scheduled to be phased out, Kurth finds a pattern: the next contract award seems to go to the producer whose last major production contract is about to end or has recently ended. Furthermore, in most cases, the new contract is for a system "similar while superior to the system being phased out," hence the term "follow-on."

The Defense Department would find it risky and even reckless to allow one of only six or seven large

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99 Samuels, p. 53.

production lines to wither and die for lack of a large production contract. There is at least latent pressure upon it from many sources to award a new, major contract to a production line when an old major contract is phasing out. Further, the disruption of the production line will be least and the efficiency of the product would seem highest if the new contract is structurally similar to the old, in the same functional category or production sector, i.e., is a follow-on contract.\textsuperscript{101}

This pattern clearly implies that maintaining employment and, even more critically, technological and industrial capacity in the military aerospace sector, is the primary criterion for contract awards for major weapon systems. As a consequence, the source selection competitions that "formally" determine who will be awarded production contracts are found to be of marginal significance.

Generally, however, a wholly different set of norms is generally used to describe the American weapons procurement process and approach to national security. As Samuels explains, while science and technology are the central fact of Japan's national security policy, in the United States it is the other way around: national security has been the central component of the American approach to science and technology.\textsuperscript{102} That being the case, analysts of American weapon system development have referred to three narrowly military core norms, characterized in this work as \textit{military-technical norms}: quality, or the expected technical performance and reliability of weapon systems; development

\textsuperscript{101} Kurth, pp. 388, 390.

\textsuperscript{102} Samuels, p. 337.
time, of the interval between the start of a development effort and the availability of operational weapons; and the cost of development.  

Jacques Gansler has postulated that the U.S military has historically emphasized the performance of weapons. "The schedule of delivery has received secondary attention, and there has been very little emphasis on the unit cost of systems. Thus, it is not surprising to find that the performance of individual weapon systems has been improving from generation to generation." Technological sophistication and performance were thought to be the United States' primary area of comparative advantage over the Soviet Union; no expense could therefore be spared to ensure the maintenance of high performance norms, and assessment of performance requirements could only prudently be made on the basis of worst-case assumptions. In fact, Gansler shows that even though the last, most sophisticated ten percent of a weapon's performance parameters accounts for about 30-50% of its cost, American weapons designers have still preferred to aim for the highest possible performance requirements. "The DoD has generally...[explained] that this is "required" for the "likely threat" that will be seen over the 25-year life


104 Gansler, p. 170.
span of the weapon system."105

Explaining Weapons Procurement Choices:
Predictions from Norms and the New Institutionalism

IV-A: It will be clear that some or all of the previously discussed types of explanations are relevant or valid under some circumstances or to some degree.

IV-B: If coherent sets of norms characterize national approaches to technology and security, then different states will respond to the same types of national security challenges in different ways. Furthermore, it will be possible to identify coherent and enduring themes that describe the ways those different states approach national security problems.

IV-C: If institutions structures are important, then institutions will serve as battlegrounds, prisms, and refractors of the inputs that come from all the other levels of analysis. States with different institutional structures will react differently to the same types of stimuli, and states with the same kinds of institutional structures will react similarly to similar inputs.

If normative and institutional explanations are not valid, the following predictions will hold:

IV-D: One level of analysis, to the exclusion of others, will consistently describe the weapons procurement behavior of a state or group of states.

IV-E: Coherent and enduring themes to describe the ways that different states approach national security challenges will not be identifiable. Different states may tackle national security problems in similar ways; no patterns, grounded in the history and geostrategic position and responsibilities of a state, will be discernible.

IV-F: If institutional structures are irrelevant, then states with different institutional structures might react similarly to the same types of stimuli, and states with the same kinds of institutional structures might react quite differently to the same inputs.

105 Gansler, p. 230.
Compatibility Among Various Approaches

We have now reviewed a variety of different approaches to explaining state behavior and constructed sets of predicted behaviors to support each approach. To what degree are these sets of explanations compatible, if we insist that each approach be applied in its purest theoretical form? Clearly the international system perspective cannot coexist with organizational and bureaucratic politics explanations. If a weapon system development emerges as an unblemished response to a carefully considered perceived threat, then that development process will not be muddled with bureaucratic or organizational games. Conversely, if organizational or bureaucratic politics is being played to the hilt, then considerations of the threat are rendered largely irrelevant.

The organizational and bureaucratic perspectives, however, are quite compatible. Organizations have bureaucratic interests. Bureaucratic players may represent organizations and act on their behalf. Classic organizational behaviors -- standard operating procedures, resistance to innovation to avoid uncertainty -- may at times serve bureaucratic interests.

The various levels of analysis can also be rendered compatible through consideration of contextual factors. Obviously the "new institutional" perspective outlined above follows this approach. Other methods along these lines may have to do with the relative stability of the international
environment; when the distribution of power in the international system is well-defined (for example, during the bipolarity of the East-West rivalry during the Cold War), then national strategies of weapons procurement policy may be more likely to hinge on international systemic factors. When the definition and stability of the international system can no longer be taken for granted, however, perhaps the relative weight of domestic factors increases.\textsuperscript{106} In the most tumultuous post-Cold War international environment, in which threats are not easily identified, characterized, or measured, domestic-level factors would predominate, according to this perspective.

Another set of contextual variables which permit compatibility between levels of analysis are the different stages of the policy process. Ample theoretical precedent supports the application of this idea, dividing the policy process into two or more stages, to cases of weapons research, design, and procurement; clearly this is Evangelista's approach. Rather than using the language of international relations theory, discussions of choice and innovation in weapons (and other) technologies often discuss the dynamics of technology-push and demand-pull. These notions are readily made analogous to the impact of the international system and domestic levels of analysis: demand-pull implies that states'
responses to threats from the international system require the development and deployment of specific weapons systems, incorporating specific technologies, in order to respond to those threats; technology-push indicates that sub-system level factors, either technological or political, drive weapons developments forward with little regard for the realities of the demand (threat) environment. In the latter case, personal, political, or organizational interests attach to particular systems or technologies.¹⁰⁷

Decades of study of the factors driving generic technological innovations have suggested that neither technology-push nor demand-pull predominate systematically, but that patterns can be discerned relating to different stages of the development of various products and industries. In general, the finding is that technology-push tends to be

¹⁰⁷ Much of this debate centers on the work of J. Schmookler, Invention and Economic Growth, Harvard University Press, 1966, which focuses on the demand-pull, or market-pull, hypothesis with regard to civilian technologies. Schmookler sees the emergence of new potential markets for new products and processes as the critical element in any innovative process; research, development, and design processes primarily serve to match technological possibilities with this market. Responses to Schmookler, including J. Schumpeter, Theory of Economic Development, Harvard University Press, 1934, and D. Mowery and N. Rosenberg, "The Influence of Market Demand Upon Innovation: A Critical Review of Some Recent Empirical Studies," Research Policy, Vol. 8, 1979, pp. 102-153, claim that both the theoretical and empirical evidence fails to support the exclusivity of the demand-pull hypothesis. They focus instead on supply-side theories of technological and industrial innovation, where advances in science and technology emerge from laboratories and research institutions, and creative entrepreneurship stimulates demand for the resulting new products. See also Christopher Freeman, The Economics of Industrial Innovation, Second Edition, Frances Pinter Publishers, London, 1982, pp. 109-110, 211-214.
relatively more important in the early stages of product development, while demand-pull becomes a more important driver in the later stages of the research and development process. In the language of international relations theory, from this perspective, we should expect to see domestic-level factors such as organizational or bureaucratic politics (technology-push arguments) dominating earlier stages of the weapons procurement process, and international system-led factors (demand-pull arguments) demonstrating the most explanatory power in the later stages of weapons procurement.

This work will now proceed to examine the evidence presented by the case study research. At the beginning of the discussion of each case, the findings will be broadly summarized; at the end of each case, those findings will be revisited with explicit attention to the degree to which they support the predictions derived from the theories of international systems, organizational politics, and bureaucratic politics outlined above. The concluding chapter will recapitulate the findings within the explicitly comparative framework provided by the emphasis on norms and institutions, and will suggest some lessons learned and directions for further study.

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Chapter Two:
On the Wings of Eagles: The U.S. F-15

As stated previously, the pattern with Cold War-era recent-generation fighter aircraft in the United States -- the F-15, F-16, and F-117 -- is dominated by performance norms. Early exploration and consideration of the need for a new aircraft takes place because of the perception of broad changes in the threat environment, often colored by domestic political and technological processes. This broad early activity coalesces into a specific requirement for a weapons system at a specific point in time, however, due to some catalyzing event in the international environment. This event forces a resolution of the domestic political debate over the need for the new system and its characteristics. It enables the bureaucratic and organizational players to argue that the threat is an urgent one, and therefore establishes the system firmly in the weapons procurement pipeline.

Once this stimulus is responded to, however, inevitably domestic-level factors dominate the processes of development and production. In the cases of the aircraft studied here, those domestic factors are best characterized as organizational politics dynamics driven by responses to armed service needs and desires, with the Air Force skillfully protecting its key roles and missions against intrusion from the Department of Defense and the Navy. In fact, when the Air Force and Navy find themselves under joint pressure from the
Pentagon, they adopt cooperative strategies, supporting each others' defense of core interests.

In the post-Cold War period, during which the fourth aircraft considered here, the F-22, has taken shape, that specific catalyzing event has not been necessary. Instead, domestic political interests have begun to define the threat in accordance with their own organizational and bureaucratic agendas. As the story of the F-22 is not yet complete, it is not clear whose interests will prevail, although the Air Force, as always, has played the organizational politics game with great skill. It is also not clear which norms will begin to supplant or supplement performance as the dominant norm influencing U.S. procurement behavior.

The F-15

Summary

Early thinking about what would eventually be the F-15 took place in response to broad tactical lessons relating to aircraft maneuverability learned from the experience of the Vietnam War. Immediately, however, various constituencies from the Air Force and Department of Defense began to attach their own personal interests to this potential new aircraft, making system specification and definition difficult. It was not until the Soviet Domodadovo Air Show in July of 1967, which alarmed the American intelligence community with the display of a startling number of new types of Soviet military
aircraft, that the specific decision to build a new U.S.
combat aircraft of a particular type was made.

Once that requirement began to make its way through the
procurement bureaucracy, domestic-level determinants began to
prevail. The decision to confine the F-15 to a single
mission, the air-to-air role, was made largely to
differentiate the F-15 from Navy programs then under
consideration, so that both services could forestall
Department of Defense pressures to build a common aircraft.
In this instance, the Soviet threat, specifically from the
MiG-25 Foxbat interceptor aircraft, was perhaps deliberately
exaggerated in order to enhance the requirement for that sole
air-to-air mission.

The nature of the procurement management system for the
F-15 was also dictated by service motivations, particularly
the Air Force’s response to the perceived failure of another
recent aircraft procurement, the F-111. The Air Force
instituted streamlined, risk-averse procedures for F-15
procurement management specifically to avoid the mistakes of
the past.

Broad Threat Dictates a New Requirement:
The Need for Air Superiority

During the mid-1960’s, when the idea for the F-15 was
born, it had been well over a decade since the United States
Air Force had built a fighter designed for air superiority.
The air-to-air optimized F-86 Sabre had achieved a 7:1 kill-loss ratio against Soviet MiG-15's in the Korean War. The F-86 had all the characteristics of a classic fighter aircraft: a high cockpit with a bubble canopy to provide excellent visibility for the single pilot, and a large wing resulting in relatively low wing loading (56 pounds per sq. ft.) These virtues contributed greatly to its success in Korea.

The F-89, F-94, and the century series aircraft, by contrast, were either fighter-bombers or interceptors. The F-4, which was the service's primary fighter workhorse during the Vietnam War, was developed by the Navy. It was originally conceived as an attack aircraft and was converted to an interceptor during design, but fortunately had sufficient secondary dogfighting capability to hold its own as a fighter and bomber in Southeast Asia.

Project Forecast, a 1963 United States Air Force attempt to identify future weapon system requirements, was not particularly prescient with regard to future fighter programs. It predicted that the service's fighter needs until the 1990's would best be met by F-111 and F-4 upgrades "...optimized for the air superiority role...," and that strategic bombing from aircraft able to fly higher and faster than the enemy would

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ensure air superiority.\(^3\) Almost as an afterthought, the report stipulated briefly that counterair forces must be able to destroy enemy aircraft in the air. Indeed, for quite some time, the Air Force’s attentions had been focused on the massive retaliation strategy of the mid-1950’s, and hence on the task of delivering nuclear weapons to targets in the Soviet Union. Other missions were virtually ignored. The F-105, for example, designed as the tactical nuclear bomber for the 1960’s, had virtually no conventional capability.\(^4\) American aircraft designers had turned away from the development of pure air-to-air fighters.

The doctrinal shift away from World War II and Korean War-era dogfighting principles of air-to-air combat was a result of advances in radar and electronics, primarily the development of beyond-visual-range missiles. Earlier, interceptor aircraft waited until they acquired enemy bombers visually, and then shot them down with rockets. New technologies allowed fighter aircraft to fire missiles at targets seen only on their radar screens, seemingly rendering the traditional dogfight obsolete. The problems with this technology appeared as soon as it was applied in Vietnam. The

\(^3\) Jenkins, 1990, p. 1.

new electronics and missiles were unreliable, and the entire battle scenario differed substantially from the theoretical exercises of the 1950's and 1960's.\(^5\) The Air Force had for years assumed that high top speed ensured adequate air superiority capability, basically simply extending the lessons of World War II and Korea into the supersonic requirements for new fighters in the 1950's and 1960's. The Air Force had no actual experience before Vietnam with air combat at supersonic speeds, and the only test of their assumptions was in exercises and maneuvers which pitted similar aircraft against each other, all operating under the same high-top-speed assumption.\(^6\) The experience of Vietnam, where American aircraft flew against highly maneuverable Soviet MiG's, revealed the defects in the United States Air Force philosophy of air superiority, along with the inability of existing American hardware to do the job.\(^7\)

Because the politics of the war put American pilots almost exclusively over enemy airspace, the task of distinguishing friend from foe without the benefit of visual identification became a difficult one. During exercises, the enemy had always approached from one side, and friendly forces

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\(^6\) Coulam, 1977, pp. 341-342.

from the other; all of the blips on the radar "on the other side" were the enemy, and therefore were eligible targets. In the real world, pilots did not enjoy the luxury of a scope clearly displaying only incoming enemy aircraft; the surrounding airspace was instead cluttered with friendly and unfriendly aircraft flying from all axes.\textsuperscript{8} Identify Friend or Foe (IFF) systems were developed, but they proved unreliable.\textsuperscript{9} This situation required that the F-4, an interceptor aircraft flown by pilots trained for interceptor missions, gear up instead for a dogfight, since visual acquisition had become one of the primary rules of engagement. As a result, the kill-loss ratio for the United States Air Force, fighting against smaller, cheaper, and more maneuverable Soviet MiG's in Vietnam, was slightly over 2:1, compared to a 10:1 ratio in Korea against essentially the same aircraft. It was increasingly obvious that the fighter-bombers and interceptors used by the United States in Vietnam were not destined to be good fighters, and in the early 1960's, the capabilities of the F-111 were difficult to predict.

Anxious to explore the ramifications of these lessons, the Air Force and Navy exercised dissimilar aircraft against one another in a series of maneuvers for the first time in 1964. These activities revealed the importance of transonic

\textsuperscript{8} Stevenson, 1978, p. 9.

maneuverability, as opposed to high top speed, for aerial combat. On January 7, 1965, Secretary of Defense Robert McNamara allocated $10 million in FY 1966 funds to modernize the existing tactical air force. Despite the fighter experience of Vietnam, however, he directed the Air Force to consider developing a new fighter "...optimized for close air support and useful in ground attack...," and to "assume" tactical air superiority in all planning.\textsuperscript{10}

Many Air Force officials were disturbed by the latter stipulation. Throughout the late 1950’s and early 1960’s, a contingent within the Air Force had been lobbying for the development of a new air superiority fighter. A study entitled "Force Options for Tactical Air" was initiated in August of 1964 under Lt. Col. John W. Bohn, Jr., to assess the service’s dependence on high-cost, high-performance tactical fighters.\textsuperscript{11} The results, released six months later, found that aircraft like the F-111 were too costly to be risked in limited, non-nuclear engagements, and recommended the acquisition of a mix of high- and low-cost aircraft as the most economical means for strengthening the tactical force.

Air Force Chief of Staff General John P. McConnell was briefed on the study in March of 1965; two days later, he was able to convince Secretary of the Air Force Zuckert of the inadvisability of assuming air superiority. In support of

\textsuperscript{10} Jenkins, 1990, p. 1.

\textsuperscript{11} Jenkins, 1990, p. 1.
this view, McConnell cited not only Bohn's study but recent Defense Intelligence Agency estimates that new Soviet interceptors presented a threat beyond the capability of existing American forces to counter.\footnote{12} In April of 1965, the Air Force began official studies of this problem, aimed at a medium-cost fighter run of 800-100 aircraft, under the generic name of Fighter Experimental (FX). General James Ferguson, Air Force Deputy Chief of Staff for Research and Development, chaired the working group. The proposed aircraft would possess "...superior air-to-air, all-weather..." capabilities, and was envisioned as having a single seat, twin engines, a stress on maneuverability over speed, and an initial operating capability (IOC) of 1970.\footnote{13}

In October of 1965, Rear Admiral Noel Gaylor, in an address to the Society of Experimental Test Pilots, recommended the development of single-mission rather than multi-mission aircraft for tactical missions.\footnote{14} This was one of the first direct counters to the traditional Air Force philosophy of designing tactical aircraft for combined strike, fighter, and close support roles. Other high-ranking Air Force officials at the same symposium argued for equipping tactical air superiority fighters with guns, in anticipation

\footnote{12} Jenkins, 1990, p. 1.
\footnote{13} Jenkins, 1990, p. 2.
of fights at close range where positive visual identification of the enemy is required -- again, reacting to the experience of combat in Vietnam.

Also in October of 1965, the service asked for funding to begin full-scale studies, releasing Qualitative Operations Requirement (QOR) 65-14-F for an "aircraft capable of outperforming the enemy in the air." The fighter was to have a high thrust-to-weight ratio, an advanced air-to-air radar, a top speed of Mach 2.5, and infrared short-range and radar-guided beyond-visual-range missiles.\textsuperscript{15}

\textbf{Defining the Requirement: The Air Force vs. The OSD}

Despite the evidence, the Air Force continued to struggle with the question of air-to-air versus air-to-ground capabilities for its next fighter. The Office of the Secretary of Defense, in particular the Systems Analysis division, was still enamored of the principle of commonality, in which the Air Force and the Navy would share aircraft designed to perform multiple missions. In July of 1965, McNamara directed the Air Force and the OSD to conduct a joint study to select either the F-5 or the A-7 for the close air support role, and as a lower priority, he endorsed the Air Force’s effort toward the new FX fighter. In November, the Air Force settled on the A-7, clearing the way for the FX as a "more sophisticated, higher-performance aircraft...as an air

\textsuperscript{15} Jenkins, 1990, p. 2.
superiority replacement for the F-4..."\textsuperscript{16}

Under considerable political pressure, however, the FX statement of work was instead revised to call for an aircraft with the best possible combination of air-to-air and air-to-ground capabilities, as opposed to the previous QOR-65-14-F air superiority description. Although this requirement changed the basic characteristic of the aircraft, it permitted the project to gain sufficient political support in the OSD to go forward. These revised specifications were therefore incorporated into a request for proposals for a Tactical Support Aircraft issued to 13 airframe contractors on December 8, 1965.\textsuperscript{17} North American, Rockwell, Lockheed, and Boeing won contracts to conduct the four-month Concept Formulation study; Grumman and McDonnell Douglas, having lost the official competition, funded their own in-house studies throughout 1966. With five variables -- avionics, maneuverability, payload, combat radius, and speed -- under consideration in terms of weight and cost, the contractors put forth about 500 prospective designs. In order to accommodate the dual missions, the contractors all agreed on the need for an advanced avionics system, a variable-sweep wing, and a high-bypass ratio turbofan engine. The typical design weighed more than 60,000 pounds and required extensive use of advanced

\textsuperscript{16} Jenkins, 1990, p. 2.

\textsuperscript{17} Stevenson, 1978, p. 10.
materials in order to achieve a top speed of Mach 2.7.\textsuperscript{18} The Air Force was not satisfied with any of the official proposals submitted, primarily because of the aerodynamic configurations and engine bypass ratios, and therefore selected none for further development.

Air Force Chief of Staff General John F. McConnell later explained that the difficulty getting the FX off the ground in 1965 stemmed from the problems of satisfying all the relevant constituencies as to what the aircraft should be.\textsuperscript{19} Even within the Air Force, according to McConnell, quite a few people wanted to make the FX into another multirole, F-4 type of aircraft. "Part of the delay was the Air Force's fault, and part is the fault of the Office of the Secretary of Defense that they did not agree with what we wanted and we had to do a lot of backing and filling together."\textsuperscript{20} McConnell clarified that there were three reasons for the delay: the fact that the Air Force could not decide whether it wanted multimission or pure air superiority capability; the program was tied up with the Navy's VFAX; and the Air Force could not satisfy the Director of Defense Research and Engineering in the Office of the Secretary of Defense that it had specified

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\textsuperscript{18} Jenkins, 1990, p. 2.
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\textsuperscript{19} See McConnell's testimony in Tactical Air Power Program, hearings before the Preparedness Investigations Subcommittee of the Senate Armed Services Committee, 90th Congress, 2nd Session, 17 May 1968, pp. 92-93.
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\textsuperscript{20} McConnell, in Tactical Air Power Program, May 1968, p. 93.
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complete aircraft parameters and defined them adequately in the FX requirement.\textsuperscript{21} Even in mid-1969, the single- versus dual-service aircraft issue was not closed; a senior Navy official, in an obvious bid to strengthen the F-14 program, argued before Congress that the F-14 could be built to meet Air Force specifications. The implication that the F-15 would not be needed was obvious.\textsuperscript{22}

Early in 1966, the Department of Defense began to consider the commonality of the Air Force's FX concept and the Navy's VFAX attack aircraft concept in order to determine whether a single aircraft could meet the requirements of both services in the 1970's.\textsuperscript{23} At that time, a Pentagon official assumed that "the day [had] passed when two independent weapons systems with essentially the same performance and mission can both win DoD approval beyond the study stage."\textsuperscript{24} It was assumed that the Air Force and Navy were already exchanging data on requirements and technologies on an informal basis, and that the blending of data would produce a stronger all-around aircraft for both services. The mistakes

\textsuperscript{21} Tactical Air Power Program, May 1968, p. 121.


\textsuperscript{23} "Industry Observer," Aviation Week and Space Technology, 10 January 1966, p. 23.

of the F-111 program were prominent in the minds of aircraft planners at this time; their goal was "to see if we can’t rationalize the specifications before we start this time, to avoid having some of the difficulties we faced in the F-111 program."\textsuperscript{25}

As of April 1966, the FX had been defined as a Mach 3 ground attack and intercept aircraft, intended to function as a superior air-to-ground fighter as well as a counter to the expected Soviet bomber threat of the mid and late 1970’s; United States intelligence sources indicated that the construction of a Mach 3 bomber was well under way in the Soviet Union.\textsuperscript{26} Later in 1966, it was reported that the speed requirement was being pushed even higher toward Mach 4.\textsuperscript{27} Clearly many designers were still preoccupied with the issue of top speed: one veteran commented in early 1967, "It’s ridiculous to build an aluminum Mach 2.8 interceptor that won’t even be able to overtake an advanced SST. It should be a titanium design and able to do better than Mach 3."\textsuperscript{28}

\textsuperscript{25} Secretary of the Air Force Harold Brown, testifying in \textit{Hearings on Military Posture and H.R. 13456 To Authorize Military Appropriations during the FY 1967}, before the House Armed Services Committee, 89th Congress, 2nd Session, 5 April 1966, pp. 7714-7715.


\textsuperscript{27} "Industry Observer," \textit{Aviation Week and Space Technology}, 26 September 1966, p. 23.

Part of this dissatisfaction undoubtedly arose from the fact that the initial requirements were for a multirole aircraft that the bulk of the Air Force did not want. In response to the revised statement of work, Tactical Air Command commander General Gabriel P. Disosway and his counterparts in USAF and PACAF issued a "twelve-star" letter (three four-star generals) which stated succinctly that the air superiority mission would be severely jeopardized if the FX were compromised to accomplish both air-to-air and air-to-ground missions. They strongly urged the Air Force Chief of Staff to endorse air superiority as the sole FX mission. Although the letter attracted quite a bit of high-level attention, ultimately the service headquarters decided to follow the path of least political resistance. The Air Force continued to study and justify a fighter capable of handling both the air superiority and ground attack missions.

The Boyd Study

Eventually Air Force development planners were able to persuade Disosway to modify the FX requirements, thanks primarily to the work of Major John R. Boyd. Boyd joined the Tactical Division of the Air Staff Directorate of Requirements in October 1966; he summarily rejected the FX designs as inappropriate. In the 1950's, Boyd had produced the "Aerial

29 Jenkins, 1990, p. 2.
Combat Attack Study," a theory of move and countermove in combat between fighter planes, while a tactics instructor at Nellis Air Force Base. During 1962, while completing an engineering course at the Georgia Institute of Technology, Boyd refined and quantified his results in a study of the energy changes incurred by an aircraft during flight. In essence, he had devised a method to measure aircraft maneuverability, defined as the ability to change altitude, airspeed, and direction. He continued these studies during his next assignment as a maintenance officer at Elgin Air Force Base, where he encountered Thomas Christie, a mathematician. Together they used computer technology to confirm Boyd's theories.31

Boyd and Christie were severely criticized for working outside authorized channels, but with the aid of several high officials were able to fend off repeated attempts to terminate their studies. In May of 1964, they published a two-volume report on energy maneuverability which enabled planners and developers to compare competing aircraft directly and to demonstrate the effects of design changes on aircraft performance. In essence, Boyd's work enabled designers to make more informed design trade-offs, optimizing any combination of given weight, acceleration (which requires a large engine), turning ability (which requires a large wing),

and range (which requires a large fuel tank). Applying Boyd's theory and techniques, by the spring of 1967, Air Force designers were able to reduce the projected weight of the FX from over 60,000 pounds to slightly 40,000 pounds. The proposed engine bypass ratio was lowered, thrust-to-weight ratio increased, and top speed lowered. Boyd was also able to get the variable-sweep wing eliminated and to simplify somewhat the aircraft's electronics.

Despite Boyd's influence, many important design decisions were made not according to calculated design trade-offs, or because of the results of wind tunnel or flight tests, but on the basis of on-paper technical specifications. For example, the Air Force required that the aircraft's radar be able to detect a small object at a distance of 40 miles. This choice dictated a radar antenna about 36 inches across, which (because of the area rule of aircraft design) in turn predetermined much of the size and shape of the plane. The same was true of the initial requirement for Mach 3 speed, set in response to the supposed similar top speed of the Soviet MiG-25 Foxbat. Eventually, compromise reduced the requirement to Mach 2.7, and then 2.5, but even the reduced speed added considerably to the size, complexity, and costs of the aircraft. Exotic materials that could withstand enormous stress, and airframe adjustments, such as the use of variable

engine inlets, were necessary to make the aircraft capable of high speed flight. The advocates of a lighter-weight, air-to-air fighter saw their repeated attempts to make the plane more austere fended off primarily by the service's arguments that only a "large, capable" plane would counter the challenge presented by the Foxbat.\textsuperscript{34} The aircraft's requirements therefore were a bureaucratic compromise, satisfying both old and new theories of air combat.

In early 1967, Secretary of Defense Robert McNamara threw a wrench into early Air Force FX plans by proposing the development of an "International Fighter" that would have replaced four United States and foreign aircraft then in the design stage: the FX, and Navy's VFAX multi-mission fighter-bomber, the Anglo-French variable geometry strike fighter and interceptor, and the American-German V/STOL fighter.\textsuperscript{35} This move was partially precipitated by the failure of American efforts to sell F-111's to Germany and Japan, and partly by McNamara's well-known obsession with avoiding parallel development and production of what he felt were basically similar advanced tactical aircraft. He envisioned one basic airframe from which would then be developed variations to perform the basic missions of attack, intercept, and air

\textsuperscript{34} Fallows, 1981, p. 101.

superiority. Of the 3,000 proposed aircraft, 1,000 would go to the Air Force, 1,000 to the Navy, and 1,000 to other countries.

The entire concept was soon abandoned due to intense political opposition from many quarters: Congress, whose members were increasingly hostile toward McNamara, and who were hesitant to share sophisticated technology even with friendly foreign nations; the Air Force, which felt that it was premature to set definite requirements for its FX, and also argued that US-European (particularly French) politics would prevent the project from getting off the ground; the Navy, which was, like the Air Force, unsure that a common aircraft would fulfill its specific missions effectively; and the Europeans, who naturally wanted to look after the interests and production requirements of their own aerospace industries. Even some Pentagon officials were skeptical: "It's hard enough when two services, the contractors, the DoD and Congress are all involved with a major development. When you add a second country you double your problems. Now imagine trying to build an airplane on the floor of the United Nations."36

A Specific Threat Event Catalyzes Requirement Definition: The Domodedovo Air Show

Through the beginning and middle of 1967, there was no overt activity on the FX, although the Air Force maintained its own Concept Formulation study team behind the scenes during that period. Part of this inactivity had to do with a general delay in advanced military projects as the Pentagon struggled to keep its budgets within White House-imposed restrictions to cope with the accelerated costs of the war in Vietnam. In July of 1967, the Soviet Union provided a jolt to American air planners with their exhibit of six new aircraft designs, including the MiG-25, and upgrades to several older planes at the Domodadovo air show. The Air Force intelligence community was quick to respond. In August 1967, the Air Force issued a second Request for Proposals to seven contractors for a Concept Formulation Study, intended to refine the concept this time for a Tactical Fighter Aircraft.

The Air Force argued vehemently this time for the importance of air superiority, without which other aerial missions such as close air support and interdiction would either be too costly or impossible to conduct. The service


intentionally made the other parameters at this point quite vague, specifying an aircraft capable of 1.5-3.0 Mach. The RFP specified four main topics of discussion: validating performance in a wind tunnel; matching propulsion requirements to achieve desired performance, including maneuverability; refining avionics and armaments (missiles, guns, or both); and determining crew size (one or two men). McDonnell Douglas and General Dynamics won this six-month competition on December 1, 1967. Fairchild-Republic, Grumman, Lockheed, and North American participated in the study on company funds.

At this time, the Department of Defense also decided that the final decision on whether to meld the FX program with the Navy's VFAX would not be made until after the conclusion of these contractor FX studies. The Air Force campaign for a separate aircraft was already in full swing. High-level Air Force testimony before Congress in early 1967, for example, speculated that it might be possible to incorporate similar avionics and propulsion systems in the two services' aircraft, but that "it is very difficult to optimize the airframe for two different missions." Clearly the decision to optimize the FX for the air superiority mission was at least in part


made in order to differentiate it from the Navy requirement, although the Air Force continued to refer the aircraft as a proposed "advanced interceptor and strike fighter" through early 1968.\footnote{41}

The General Dynamics Concept Formulation study group provided recommendations for both a fixed-wing and variable geometry FX; McDonnell Douglas focused on a fixed wing, two engines, and a one-man crew.\footnote{42} In September 1968, having received the contractors' results in May, the Deputy Secretary of Defense approved the FX Concept Development paper. Basic airframe issues were resolved quickly, but the composition of the avionics suite caused considerable disagreement. The multi-purpose aircraft advocates argued for the retention of such features as terrain-following radar and blind-bombing capabilities. They argued that future technological advances would permit sufficient cost and weight reductions to make a multi-role aircraft feasible. The Concept Development Paper therefore left many issues unresolved.\footnote{43}

Several significant events occurred in 1968 that shaped the course of the FX program. First, the Navy had become disenchanted with its version of the F-111 and had therefore gone ahead with the study and development of its own fighter,
the VFAX/VFX/F-14. This event presented the Air Force with a clear foil, and the opportunity to define the F-15 solely for the air-to-air mission in order to differentiate itself. Second, the Presidential elections resulted in changes in the White House and in the Pentagon. Since the OSD still dwelled heavily on the idea of commonality, the Air Force took care to make its FX requirements sufficiently different from the Navy's aircraft in order to justify continued development. In addition, in order to get the program far enough along in development to protect it from cancellation by the new administration, the Air Force decided to skip the prototype phase and proceed directly to full-scale development as quickly as possible.\textsuperscript{44} The first true requirement for the FX therefore came in February of 1968, when TAC's General Disosway issued Required Operational Capability (ROC) 9-68; the ROC was simply a restatement of the original air superiority QOR-65-14-F. Three months later, the Air Force Chief of Staff designated the FX as the Air Force's top priority development program.\textsuperscript{45}

\textsuperscript{44} Jenkins, 1990, p. 3.

\textsuperscript{45} Jenkins, 1990, p. 3.
Defining the Requirement: Foxbat

The threat presented by the Soviet MiG-25 Foxbat had become a point of contention in setting the technical and tactical requirements for the F-15. It later became clear that an overestimation of the MiG-25's capabilities substantially and unnecessarily increased the F-15's size and cost. In the late 1960's, the Foxbat was reported as having a dash speed of Mach 3.2 or better, with the capability to sustain Mach 2.8 for more than 18 minutes, and a combat range of 2,000 miles; these numbers were the principal justifications for the F-15's high speed, large radar, and high cost. The Air Force Chief of Staff at the time, John P. McConnell, testified before Congress that, in light of the threat from the Foxbat, the FX was "coming in a little too late." 46 The Senate Armed Services Preparedness Investigating Subcommittee later attacked the Pentagon's tactical air procurement program for insufficient new fighter starts during a period of heavy Soviet procurement activity. 47

Both the Air Force testimony before the committee and the committee report urged that the FX be optimized for an air

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superiority role, and that this not be compromised by burdening it with additional missions. McConnell explained in the May 1968 hearings the critical importance of air superiority. "Once you gain air superiority over a battlefield, you can use A-7's, PT-3's, or anything else that can fly and haul ordnance. The first thing you have to achieve is air superiority." When asked whether he envisioned the FX ever being used for close air support, McConnell replied, "It would be over my dead body."48 General G. P. Disosway, commander of Tactical Air Command, further clarified the Air Force's position on dual-mission aircraft: "Having one aircraft to do everything would have been fine, I guess, back in World War I, when technological developments had not come as far as they have. But if you are going to build one airplane to do everything, and I am going to build two airplanes, one of them to do one thing very well and another to do just one thing, then I can beat your airplane in both missions."49 The committee report placed the blame for the perceived "fighter gap" squarely on Pentagon insistence that the Air Force develop multiple mission aircraft, and further


accused the Pentagon of blocking the development of the FX over the previous several years in order to protect the F-111 program.

The report also claimed that the Department of Defense used the acknowledged United States numerical advantage in air-to-ground tactical aircraft to justify a conclusion that the United States had overall tactical air superiority over the Soviet Union, intentionally overlooking the air-to-air mission. Symington, one of the authors of the report, commented, "Because of this premise of 'commonality' -- one plane to handle all future missions -- promoted and pressed by inexperienced civilians, along with a shortsighted, pennypinching policy on all other possible designs, today and for the immediate future, the United States is faced with a potential second place in air power."\(^{50}\)

The Department of Defense clung to the multi-mission concept even in the face of these arguments. In the May 1968 tactical air power hearings, Dr. Alain Enthoven, Assistant Secretary of Defense for Systems Analysis, continued to argue in favor of a multi-mission FX. He explained that in the type of future air war he envisioned, air-to-air combat, although significant, would not be the dominant part of the air battle. Citing the fact that of 1,500 United States aircraft lost in Southeast Asia, only 48 were lost in air-to-air combat, he claimed that the key to achieving air superiority is bombing

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\(^{50}\) Winston, 14 October 1968, p. 21.
enemy air bases and destroying enemy aircraft on the ground.\footnote{Tactical Air Power Program, 6 June 1968, pp. 189-191.}

The subcommittee remained concerned that the Air Force and Navy aircraft would be merged; while the Air Force had been staunch in demanding a single-role aircraft, Congress sensed that the Department of Defense remained unconvinced. Indeed, in early 1968, the Director of Defense Research and Engineering, Dr. John S. Foster, Jr., testified that "the significant savings of a joint fighter program places a premium upon exploring every avenue leading to commonality which does not unacceptably compromise the requirements of either service."\footnote{Foster, testimony in Authorization for Military Procurement, Research, and Development, FY 1969, and Reserve Strength, hearings before the Senate Armed Services Committee, 90th Congress, 2nd Session, 15 February 1968, p. 477.}

The tremendous political fervor generated by the Domodedovo air show and the inflated estimates of the Foxbat’s capabilities were instrumental in the FX’s emergence as an aircraft with an identity of its own, albeit in order to face an at best ill-defined threat.\footnote{"New Soviet Fighters Spur DoD Programs," Aviation Week and Space Technology, 29 July 1968, pp. 18-19.} Another senior Air Force official later testified that the reason the F-15 procurement was so successful was that the program was stable, without much of the baggage that had plagued the F-111 program: it was a single-service aircraft, without another service’s pressure
to make changes; similarly, it was a single-purpose aircraft; and finally, the measurable performance milestone approach permitted positive program control and good program visibility, so that the Air Force could obtain exactly what it wanted at a reasonable cost.\footnote{Brig. Gen. Roger K. Rhodarmer, Assistant to the Deputy Chief of Staff for Research and Development for the F-15, testimony in \textit{Hearings on Military Posture and Legislation to Authorize Appropriations During FY 1970}, before the House Armed Services Committee, 91st Congress, 1st Session, March 1969, p. 3273.}

The Air Force came under considerable fire in Congressional hearings throughout 1968 because the projected performance characteristics of the FX were little better than those projected onto the Foxbat. Senator Stuart Symington, who had served as the first Secretary of the Air Force, complained vigorously that the Air Force was planning for an American aircraft to come on line in future years that could barely compare with what they thought the Soviets had at that time;\footnote{"Soviets May Be Shifting Design Emphasis," \textit{Aviation Week and Space Technology}, 5 August 1968, pp. 32-33.} it was difficult to explain to the Congress that the two aircraft were designed for entirely different missions and hence should not be matched characteristic for characteristic.

Ironic lessons were learned in 1976 when, after the F-15 was well into the procurement pipeline, Soviet Lt. Victor I. Belenko defected and flew his MiG-25 to Japan. His hardware and testimony revealed that American intelligence estimates had grossly overestimated the Foxbat's capability. The Soviet
aircraft in reality could not exceed Mach 2.8, and pilots were instructed not to go above Mach 2.5. The United States had correctly tracked a Foxbat at Mach 3.2 over Israel in 1973, and knew that it had later reached Egypt with its engines completely burned out. What the Americans did not realize was that the engine destruction was an inevitable consequence of flying the aircraft at that speed, not a one-time accident. Belenko also confirmed that the Foxbat's actual combat radius was less than one-fourth the original American estimates.\(^5^6\)

In addition, regardless of the accuracy of the estimates of the MiG-25's capabilities, the Soviet aircraft was designed solely for high-altitude intercept missions against American bombers and reconnaissance planes. It was therefore extremely unlikely ever to see, let alone engage, the F-15 in aerial combat.\(^5^7\) The experience of setting the technical and tactical requirements for the F-15 was therefore prototypical of a phenomenon observed by Benjamin Lambeth:\(^5^8\)

... tendency to produce statements of "need" based more on the outer limits of what is technologically feasible than on what performance spread is actually called for by most real mission demands. More often than not, the result is to overdesign against the threat by incorporating impressive capabilities of questionable actual value.

In August 1968, the Air Staff issued a supplement to the

\(^5^6\) Fallows, 1981, pp. 70-71.

\(^5^7\) Lambeth, Fall 1985, pp. 89-90.

\(^5^8\) Lambeth, 1985, p. 96.
Concept Formulation Package which incorporated fundamental changes to the original. The service's air superiority doctrine was clarified, firmly espousing the expectation of close-in air-to-air combat and therefore affirming the need for a fighter capable of such tactics. The Package noted one other primary lesson of Vietnam, that smaller aircraft could better escape enemy radar and visual detection. The wing planform remained an open issue, although the "representative FX" described in the Package described a swing-wing design. The major subsystems, according to the plan, would be produced on a competitive prototype basis in order to reduce potential risks. By September of 1968, the multi-mission role had been abandoned in favor of a pure air superiority fighter designed for either air-to-air sweeps over enemy territory, or for escort of tactical bombers.

The final task in the concept formulation phase was the preparation of the Development Concept Paper (DCP). This document, released at the end of the summer of 1968, described a "single-seat, twin-engine aircraft featuring excellent pilot visibility, with internal fuel sized for a 260 nm design mission, and a balanced combination of standoff (missile) and close-in (gun) target kill potential."

The decision to include only one crew member was intended as much to differentiate the aircraft from its Navy counterpart as it was to save the 5,000 pounds in additional structure and systems.

59 Jenkins, 1990, p. 3.
The twin-engine design was selected because of its faster throttle response and earlier availability; safety factors do not seem to have played a role. The DCP estimated costs at $1.078 billion for R&D and a flyaway cost of $5.3 million per copy base on a production run of 520 aircraft.\textsuperscript{60}

The F-15 was built not so much to counter the threat from a specific enemy aircraft as to overcome a trend.\textsuperscript{61} The Domodadovo air show had been a shock to the United States intelligence community. The Soviets for years had primarily built aircraft designed for point defense, with limited range, but small enough to be built in quantity and deployed relatively densely around the country's borders and provide homeland defense. As the Soviets' perceived threat changed, so did their design philosophy, resulting in an increase in air-to-air missile launch range, radar search range, thrust-to-weight ratio, and wing loading -- in other words, a capability for beyond-visual-range engagement, similar to American Air Force developments. In terms of dogfighting, however, these trends were not all positive. High thrust-to-weight ratio provides maneuverability, since more thrust provides more energy or velocity. High wing loading, however, decreases maneuvering performance. The trend followed by both the Soviets and Americans as this time was therefore to design aircraft which could dash out at top speeds to intercept an

\textsuperscript{60} Jenkins, 1990, p. 3.

\textsuperscript{61} See Stevenson, 1978, p. 12.
incoming threat.

The Soviets, however, also continued to produce versions of aircraft like the MiG-21, with interceptor-quality speed but no complementary armament, thereby decreasing the wing loading and therefore having the ability to engage in competent maneuvering dogfighting. These Soviet air-to-air fighters were proving to be quite capable in Vietnam. Indeed, in early 1968, the North Vietnamese (flying Soviet aircraft) achieved a positive kill-loss ratio over American pilots.

The United States Air Force, observing this trend, concluded that dogfighting capabilities were of the utmost importance for its new fighter. It also observed, however, that beyond-visual-range air-to-air missile launch would remain important, and that the ideal aircraft would therefore be one with the maneuverability of a dogfighter but retaining the beyond-visual-range and dash speed qualities of an interceptor. In terms of aerodynamic design, this translated into a combination of low wing loading and a high thrust-to-weight ratio; in terms of avionics, it meant a capable interceptor-type beyond-visual-range weapons system. 62 This new set of problems was assigned to the competing contractors in the September 1968 Request For Proposals. It included a wing optimized for buffet-free performance at 0.9 Mach at 30,000 feet; a high thrust-to-weight ratio to achieve high energy maneuverability throughout the flight envelope when

combined with the wing criteria; global ferry range capacity with or without in-flight refueling; and one-man operation of the weapons systems for all missions. In order to reduce procurement risks, both the radar and the engines were developed and tested in an Air Force-funded competitive prototype development and test program parallel to the airframe study and proposal effort.\textsuperscript{63}

Westinghouse Electric Corporation and Hughes Aircraft Company were awarded contracts on November 5, 1968, for competitive attack radar development programs, with a fly-off for production twenty months later. General Electric and Pratt & Whitney won competitive 18-month engine development contracts in August 1968 awarded jointly by the Air Force and Navy for the F-15 and F-14 fighters. Hughes and Pratt & Whitney were the respective winners. The contract to develop the 25-mm caseless ammunition gun was awarded, in a similar competitive fashion, to Philco Ford.\textsuperscript{64}


Contract Definition and Source Selection

On September 30, 1968, the Air Force released an RFP for Contract Definition to eight airframe firms; three months later, McDonnell Douglas, North American, and Fairchild Hiller were awarded $15.4 million Contract Definition contracts. The participants were instructed to consider possible joint aircraft production with the Navy in their designs. The technical proposals were due on June 30, 1969, with projected costs and schedules to follow two months later. The RFP specified what the Air Force was looking for: a wing with low loading optimized for buffet-free performance at 0.9 Mach; a high thrust-to-weight ratio; ability to ferry to Europe without aerial refueling; a one-man cockpit and weapons system; a fatigue life of 4,000 hours under normal fighter operations; a low maintenance man hours per flight ratio of 11.3:1; 360 degree visibility from the cockpit; self-contained engine starting with no ground support equipment required; a maximum gross take-off weight of 40,000 pounds; a maximum speed of Mach 2.5; a long-range pulse-Doppler radar with look-down/shoot-down capability; and low development risk. The Source Selection Evaluation Board (SSEB), chaired by Program Manager Brig. Gen. Benjamin Bellis, evaluated the three proposals along 87 separate factors under four distinct categories: technology, logistics, operations, and management. The SSEB's ratings were passed on to the Source Selection

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65 Jenkins, 1990, pp. 3-4.
Advisory Council (SSAC), chaired by Air Force Systems Command commander Major General Lee V. Cossick. Using a predetermined set of weighting factors and evaluation criteria, the SSAC selected a winner. On December 12, 1969, McDonnell Douglas' 2.5 million-man hour, 37,500-page proposal netted it prime contract number F33657-70-0300 for this new fighter aircraft, now officially dubbed the F-15.\textsuperscript{66}

Apparently several factors mitigated against North American Rockwell's proposal in the source selection decision: the lack of authority delegated to the program manager, a unit cost 7-8% higher than McDonnell Douglas' proposal, and an avionics program judged as too complex. Another factor in McDonnell Douglas' favor may have been its decision not to build a new manufacturing facility, in contrast to the other two competitors.\textsuperscript{67}

**The Lightweight Fighter Advocates**

Not everyone agreed that the F-15 was the proper aircraft to buy. The most prominent alternative, the F-XX, was proposed by OSD systems analyst Pierre Sprey in July of 1968. He, along with other members of what came to be known as the "lightweight fighter mafia" (which included John Boyd),


believed that the F-15 was too expensive, incorporated too much high-risk technology, was unnecessarily complex, and would not achieve its advertised air superiority performance. Sprey's F-XX was a 25,000 pound, single-seat, single-engine fighter designed specifically to fight in the subsonic and transonic regions. The F-15 was to be designed for high maneuverability at supersonic speeds up to about Mach 2. The capability to dogfight dictated supersonic speeds in order to arrive at the air battle, but once engaged, fighters almost invariably slowed to around Mach 1, and high maneuverability rather than speed became the key to victory. 68 Indeed, the F-15's top speed became quite a contentious issue. The lightweight fighter advocates, led on this issue by Everest Riccioni, trumpeted an old pilot's saying: "An airplane will reach Mach 2 just in time to run out of fuel." 69 Fuel consumption rises sharply as an aircraft approaches Mach 1, and even more when the afterburners are turned on to maximize thrust and achieve supersonic speeds. According to a paper Riccioni authored in 1978, not one second of flight combat time above Mach 2 was recorded in Vietnam, and extremely little above Mach 1.2. "The vast majority of military

68 Lyons, 1986, p. 20. For early indications that at least some elements of the Air Force were beginning to realize that high speeds were not critical for maneuverability, see Hans Multhopp, "The Challenge of the Performance Spectrum for Military Aircraft," Air University Review, May-June 1966, pp. 30-39.

operations and all heavy combat maneuvering was done in the
domain of speeds below 1.2 Mach....Even the time at 1.6 proves
my point. The became prisoners, pilots who ran out of
fuel.\textsuperscript{70} Employing fixed wings and two Sidewinder missiles,
Sprey's F-XX shunned complex avionics, instead featuring a
simple visual radar, easy and inexpensive maintenance, and a
unit cost of only $2 million. The proposal also included a
VFXX version for the Navy.\textsuperscript{71} The services, however, were far
from persuaded by Sprey's arguments. They cited the short,
unsuccessful experience of similarly equipped F-104's in
Vietnam, and the limitations of the small F-5, as examples of
the inadequacy of lightweight fighters.\textsuperscript{72} Many Air Force and
Navy pilots, however, were impressed with the F-XX proposal;
indeed, simulations and flight tests during 1968 under the
names Project Feather Duster and Have Doughnut demonstrated
the superior maneuverability of a lightweight fighter against
F-4E's.\textsuperscript{73} The idea had considerable merit, but clearly was
before its time. The F-14 and F-15 projects were too far
along to be sidetracked; all the F-XX succeeded in doing was
further uniting the Air Force behind the single-mission F-15.

\textsuperscript{70} Fallows, 1981, p. 45. On this point, see also Major Buddy
Bowman, "To Fly and Fight," \textit{USAF Fighter Weapons Newsletter},

\textsuperscript{71} Jenkins, 1990, p. 3.

\textsuperscript{72} "Washington Roundup," \textit{Aviation Week and Space Technology},
23 June 1969, p. 15.

\textsuperscript{73} Jenkins, 1990, p. 3.
The lightweight fighter idea would, of course, resurface later in the YF-16/YF-17 program.

Protecting Organizational Interests and Needs: F-15 Design and Procurement Strategy

McDonnell Douglas had never won an aircraft competition on paper (having lost on the F-111 and VFX); in contrast, it had never lost a prototype competition. Its main advantage in the FX competition was its experience in designing carrier-based aircraft for the Navy. The Air Force had never before been interested in flight at slow speeds and high angles of attack, but a maneuvering air combat aircraft incorporated both these characteristics. The trade-off studies related to the wing focused on lift-to-drag ratio, as opposed to the emphasis on cruising in the past. There was little existing research in this area, even at NASA, usually the Air Force’s primary source of wind tunnel data. McDonnell Douglas therefore tackled the problem itself, keeping three wind tunnels operational almost around the clock for nearly a year. The ultimate wing was selected from almost 800 analyzed configurations, with 107 wings tunnel tested. By way of comparison, the total number of wind tunnel hours before first flight on the F-4 had been 4,287; on the F-15, 22,188.

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74 On the technical problems encountered in these lift-to-drag ratio studies, see Jenkins, 1590, p. 20.

75 Stevenson, 1978, p. 15.
On the airframe, McDonnell Douglas experimented with aircraft from 25,000 to 100,000 pounds, and a total of 68 point designs. One of the contractor's internal design groups used Computer Aided Design and Evaluation (CADE) to optimize fighter design characteristics along with costs and generic engine designs. These CADE studies showed that virtually unlimited Specific Excess Power (the power the aircraft has remaining to climb or turn when maneuvering) is achievable, but that it requires unlimited funds.

One of the primary considerations in the design stage was whether to make the F-15 a one-man or two-man aircraft. Colonel John Boyd, then of the 8th Tactical Fighter Wing, was instrumental in driving the Air Force toward the one-man concept. Standard procedure during the Vietnam War had been for Ground Control personnel to tell the pilot whenever enemy aircraft were approaching him. Since opposing aircraft generally attempt to come from the rear, the pilot's first move would be to perform a 180 degree turn. The resulting rapid rate of closure resulted in poor coordination between the pilot and his back seat missile operator; the Air Force therefore accomplished few good missile shots. In addition, the Air Force did not assign dedicated missile operators as the Navy did; usually they were pilots putting in their time until they could get into the front seat. Those Air Force

76 For more detail on the CADE studies, see Stevenson, 1978, pp. 16-18.
backseaters who were dedicated Weapons System Officers (WSO) did not regularly fly with the same pilot (again, unlike Navy policy), contributing further to the coordination problem. The Air Force learned from this experience, at Boyd's urging, that the automation in the F-15 would permit one man to coordinate and perform all the jobs.\textsuperscript{77}

Another primary design consideration in the F-15 program was variable sweep as opposed to fixed wings. While it was recognized that variable geometry solves many aerodynamic problems, it also creates additional cost, weight, and maintenance problems. The main function of the variable sweep wing is to expand the aircraft flight envelope, and to enlarge the point design area so that the aircraft is optimized for a larger area in the flight envelope. The F-15 design, however, offers another solution. The Air Force's evaluation of the dogfights which took place in Southeast Asia led them to conclude that most dogfights take place at between 0.6 and 1.2 Mach, and below 30,000 feet. Because of prohibitive fuel consumption rates and the impossibility of tight turns, speeds much above Mach 1.4 are "virtually useless" in maneuvering air combat.\textsuperscript{78} The F-15 was therefore designed primarily for that arena, disregarding the additional loiter and endurance time

\textsuperscript{77} Stevenson, 1978, p. 18.

available from forward swept wings.\textsuperscript{79}

Beginning in March of 1970, NASA conducted an early independent laboratory evaluation of the McDonnell Douglas design. Finding the F-15's subsonic drag level to be higher than predicted, designers removed the ventral fins, and enlarged and altered the shape of the vertical fins. These changes produced the desired drag level improvements and also slightly enhanced stability.\textsuperscript{80}

The F-15 passed its preliminary design review (PDR) in September 1970, and the airframe critical design review (CDR) in April 1971. The CDR included the following changes from the original FX design: increased height and area for the vertical fins and deletion of the ventral fins, as a result of the NASA study; a move of the horizontal tail surfaces and wings five inches aft to improve aircraft balance; redesign of the engine air intakes with cowl fences on the upper outer edge and a new cowl lip; and a more symmetrical nose radome to enhance radar performance.\textsuperscript{81} The CDR package proposed an initial production rate of one aircraft bimonthly, increasing to one aircraft per month, and eventually to a maximum production rate of 12 per month. Structural testing of major assemblies began in December of 1971, and the first aircraft

\textsuperscript{79} Stevenson, 1978, p. 37.

\textsuperscript{80} Jenkins, 1990, p. 6.

rolled off the production line in June of 1972.

Renewed Pressure for Commonality

Deputy Secretary of Defense Paul Nitze had encouraged contractors to include the possibility of a Navy version of the F-15. McDonnell Douglas claimed that its model was adaptable to carrier service because of its excellent thrust-to-weight ratio and visibility, the only necessary modifications being strengthened landing gear and an arresting hook for carrier landings, and wing folding for carrier storage. Congress began to take several long looks at the F-14 and F-15 programs during 1971 with the goal of eliminating one in order to save money. On July 8, 1971, the Navy requested data on the F-15 as a potential fighter; the Secretary of Defense had ordered the Navy to investigate the possibility of a Navy version of the Air Force plane through the F-15 Systems Program Office. McDonnell Douglas produced a minimum modification which increased the aircraft's weight by about 2,300 pounds for carrier suitability. The Navy Fighter Study Group, however, ignored the Air Force contractor's proposal and instead did their own study, increasing the weight much more dramatically and adding a Phoenix missile. The increase in weight and drag affected cost and weight to the point that the Navy could declare the aircraft unacceptable for its purposes. In addition, Admiral Thomas Moore, the Chief of Naval Operations, and General
McConnell, the Air Force Chief of Staff, agreed to present a unified view to Congress that the two aircraft had been designed for completely different missions; the common front helped each protect his own service's program.  

The issue was reopened in March of 1973, when the Senate Armed Service Committee's ad hoc Tactical Air Power subcommittee began studying potential modifications of the F-15 for the Navy. The Navy's F-14 program was encountering Congressional and public scorn due to schedule difficulties and cost overruns, prompting Deputy Secretary of Defense David Packard to look at alternatives for the Navy mission, including lower cost F-14's, F-15N's, and enhanced F-4's. McDonnell Douglas surprised the Navy at the subcommittee hearings with a detailed proposal for a carrier-based F-15, about which the service had previously heard nothing. After a politically charged and eventually aborted attempt at an F-14/F-15 flyoff, the Navy formed a Navy Fighter Study in which all alternatives were supposedly objectively analyzed. This study concluded that the F-15 would require a major redesign in order to meet the Navy's needs for fleet air defense. The controversy eventually gave birth to the Naval Air Combat

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82 Jenkins, 1990, p. 6.


Fighter (NACF), which would ultimately become the F-18 Hornet.

**Procurement Strategy: Risk Reduction and Avoidance of Past Failure**

The Air Force and McDonnell Douglas jointly managed the F-15 program. In July 1969, Colonel Benjamin Bellis, who had successfully managed the SR-71 development, came aboard as Air Force program manager; Donald Malvern headed the contractor’s F-15 office. As a reaction to the difficulties with the F-111 and C-5 procurement programs, Deputy Secretary of Defense David Packard advocated a prototyping procurement concept rather than a paper study in order to select the winning contractor for development and production of the F-15. The General Accounting Office also recommended competitive prototyping of the F-15 in the hope of precluding extensive cost overruns.\(^5\) By the time Packard came into office, however, the F-15 program was judged to be already too far along to institute the prototyping concept, and therefore a strict milestone concept was adopted instead. Other factors mitigating against the prototyping strategy for the F-15 were the substantial additional initial costs involved, which would have necessitated cutbacks and postponements in other programs given the overall defense budget ceiling at the time, and the additional time required, which would have slowed the original schedule for production and deployment.

In keeping with this strict milestone concept, when the F-15 contract was signed on December 31, 1969, its terms, conditions, and restrictions were specified in 146 pages, rather than relying on the letter of faith agreement as the Air Force had done in the F-111 program. It combined a cost-plus-incentive-fee (CPIF) with a fixed-price-incentive-with-successive-target (FPIS) arrangement which had three major items.\footnote{See testimony by Brig. Gen. Roger K. Rhodarmer, Assistant to Air Force Deputy Chief of Staff, Research and Development for the F-15, Hearings on Military Posture, Part 2, before the House Armed Services Committee, 91st Congress, 1st Session, 9 July 1969, pp. 3290-3292.} The first, which was the only CPIF portion, covered engineering and design of the aircraft; aerospace ground equipment and tooling; Category I flight testing; contractor support for Category II flight testing; and structural, fatigue, and other pertinent testing. This item had a target cost of $588 million and a maximum 8% incentive fee. The first FPIS item included the production of 20 Category I and II test aircraft, plus spares and ground support equipment (GSE) and three static-test airframes, with a target cost of $469 million and a 9% incentive fee. The not-to-exceed ceiling price on the first wing of production aircraft was $937 million, or 145% of the target cost. There originally were not-to-exceed ceiling options on the second and third wings of production aircraft, but with inflation and constantly changing Air Force production requirements, these
options ended up being renegotiated yearly.\textsuperscript{87} The other cornerstones of this contract were 24 milestones, each of which had to be met before progressing to the next one, with real financial incentives and penalties attached. Specific test methods were applied, so that quantitative test data from the development and test programs were evaluated before large sums of production funds were committed.\textsuperscript{88} The milestones included, for example, approval of preliminary design review, radar contractor selection, first flight, specific performance criteria, completion by the Air Force of its Category II flight test program, and ultimately the delivery of the first F-15 to the Tactical Air Command. The contractor also accepted a "total system performance responsibility" clause, which placed responsibility on McDonnell Douglas for satisfactory integration of the engines and all other government-furnished equipment (GFE). The contract specified that McDonnell Douglas was responsible for correcting deficiencies, without price adjustments. Again, these clauses were included in a successful attempt to preclude the massive failings of the F-

\textsuperscript{87} Jenkins, 1990, p. 5.

111 and C-5A contracts. The service could decide unilaterally whether the contractor had met all its commitments, and could delay funding or cancel the program if it so desired. The contract also provided for more visible accounting methods than had previously been the norm. Its limitation of government obligation (LOGO) clause required McDonnell Douglas to give 17 months notice (corresponding to the government's budget cycle) for additional development funds; if additional costs were incurred on the airframe or the engine, the contractors were to pay for them from their own treasuries (or a bank's, with a bank's attendant interest rates) in the hope that they would be reimbursed. Any interest charges involved in such transactions were not to be reimbursable. Initial planning assumed the eventual production of 749 aircraft: 432 to equip three 72-plane TAC wings, two 72-plane USAFE wings, and one 72-plane PACAF wing; 108 for transition training and proficiency; 54 for command support; 12 Category I test aircraft for continued testing; and 143 aircraft for attrition.

The approach to specific technical details of the F-15 also reflected the desire to avoid the mistakes of the F-111 development program. In response to the F-111's engine-inlet compatibility problems, for example, the Air Force mapped the

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89 On the LOGO clause and other details of the contract and management system, see "ASD Pushes Total Management for F-15," Aviation Week and Space Technology, 26 June 1972, pp. 66-77.

90 Jenkins, 1990, p. 5.
entire engine-inlet interface of the F-15 before its first flight. Similarly, in the shadow of the wing box fatigue problems of the F-111, major structural testing was conducted well before the first flight of the F-15. 91 In sum, steps were taken to make the F-15 program much less concurrent than its immediate predecessor, with the aim of identifying potential technical difficulties well before they might cost significant amounts of development funds to correct, and more importantly, well before they could attract significant political attention. 92

The Air Force at the time was making a determined bid to tighten management procedures in the wake of harsh criticism of its past practices from Congress and within the Pentagon itself. One Air Force official commented in early 1970, "We want to show that we can manage a program and close the credibility gap with the public and Congress." 93 The innovative management system implemented in the F-15 program was designed to simplify and streamline the chain of command. The System Program Director (SPD), the official directly in

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charge of the F-15 procurement, reported directly to the commander of the Air Force Systems Command, who in turn reported directly up a chain to the Air Force Chief of Staff and then to the Secretary of the Air Force. Known as the Blueline Management Information System, this ensured that comprehensive program information would be collected at one point -- the Air Force Systems Command -- and move up the line in a standardized format, and that the SPD would always have immediate access to top Air Force and OSD decision makers.\textsuperscript{94} According to the then-Director of Aeronautical Systems at Wright-Patterson, this chain of communication, combined with a regular system of briefings, was critical in preventing political difficulties resulting from higher-level officials being surprised by difficulties with the program.\textsuperscript{95}

The SPD was delegated total management authority, with special emphasis on balancing performance, costs, and schedules. Bellis hand-picked the people for the Special Projects Office (SPO) at Wright Patterson. Over 90\% of the 230 personnel had previous SPO experience, and all 230 were kept with the program throughout its development phase.\textsuperscript{96}


\textsuperscript{95} Col. Richard K. McIntosh, Oral History Interview, 6 March 1973, Air Force Historical Research Center document K239.0512-968, pp. 6-7.

The management strategy also called for using known technology whenever possible, or at most a refinement of known techniques. As a result, for example, the Air Force settled for a drift error of three miles per hour from the aircraft's inertial navigation system, rather than the initial one mile per hour requirement, in order to balance requirements with costs in a reasonable way. In the end, the manufacturer used known state-of-the-art techniques to produce an inertial navigation computer that satisfied the one mile per hour drift anyway.

Extensive use was made of Computer Aided Design and Computer Aided Manufacturing (CAD/CAM). While the F-4 was 65% assembly and 35% fabrication, for example, the F-15 almost reversed these figures so that fabrication took 60% of production man-hours and assembly 40%. This resulted in the first production F-15 requiring only 11,000 man-hours of final assembly, as opposed to 35,000 for the F-4. The use of the computer is another reason that Engineering Change Proposals (ECP's) were kept to a minimum. The F-4 went through 135 costly ECP's before the first production aircraft flew, as opposed to only 38 for the F-15. In addition to the added cost of retrofits inherent in ECP's, these changes also usually add weight, which inevitably detracts from the performance of the aircraft. Because ECP's were kept to a

minimum, the weight increase from the first pre-production to the first production F-15 (the 21st aircraft overall) was only 188 pounds, while the analogous F-4's increased by 3,050 pounds.98

The F-15 ECP's resulted primarily from pilot input during the test program. Most of these were quite minor, involving technical details such as bolt linkages and re-routing of wire bundles. The three primary structural changes were the enlarged speed brake, the raked wing tips, and the snagged stabilator.99 The original speed brake caused a buffet at the desired drag configurations; the new brake, enlarged from 20 to 31.5 sq. ft., created the needed drag at lower extension angles. The snagged stabilator solved a flutter problem discovered during wind tunnel testing. By cutting the snag, a minor shift in the coefficient of pressure and a change in the moment of inertia was satisfied. The snag was a production feature of the fourth F-15 and was retrofitted into the first three production aircraft. The raked wing tips resulted from a discovery early in the test program that there was a wing buffeting problem at certain altitudes. Engineers at Edwards Air Force Base removed four sq. ft. off the tip of the fourth F-15's wing to solve the problem and create the present raked appearance.100

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100 Stevenson, 1978, p. 28.
Other early modifications did not cause changes in appearance. The landing gear, which was originally narrow by design, was not tolerant of cross winds with the control system and strut chamber then in use. A modification to the strut and several changes to the flight control system enabled the F-15 to land in 30 knots of crosswind.

In early 1972, in order to combat cost increases, the equipment list for the F-15 was pared back somewhat. The planned multi-sensor display was eliminated, as was the moving map display, the helmet-mounted sight, and the Target Identification System, Electro-Optical (TISEO). The planned vertical-tape style instrumentation was removed in favor of less expensive conventional round dials. Several other items, including the bird-proof windshield, were considered for elimination but subsequently reinstated.101

The test program was also responsible for keeping track of the maintenance required on the F-15. One of the requirements in the F-15 RFP was that the maintenance requirements be comparable to the P-51 Mustang, which required about 15 Maintenance Man Hours per Flight Hour (MMH/FH); the F-15 contract called for 11.3 MMH/FH at maturity. Early F-15 demonstration teams achieved 4.25 MMH/FH over 43 days at air shows and visits to bases in late 1974. Another maintenance requirement was a 12-minute combat turnaround time, including missile and gun ammunition loading, liquid oxygen, oil, and

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fuel service, and a quick inspection. A McDonnell Douglas team was able to demonstrate this requirement in under six minutes.¹⁰²

By far the most contentious element of the F-15 procurement program was the development of the F100 engine. The Air Force embarked on a project of tremendous technical risk by demanding a thrust-to-weight ratio of 8:1. When 4:1 was the best that had ever been designed until that time. Essentially, the engine was to generate 3,000 more pounds of thrust than its immediate predecessor but weigh 1,000 pounds less.¹⁰³ The Development Concept Paper for the F-15 program proclaimed the F100 risk acceptable largely because the advanced technologies involved had been proved in principle by demonstrator engines developed under the auspices of other Air Force programs. Early in 1973, however, the F100 failed its first Military Qualification Test (MQT), a 150-hour Qualification Test which measured sea level and altitude endurance. It passed the 81.25-hour sea level portion in January 1973 without difficulty. In the altitude chamber in February, however, the engine’s fan and turbine encountered problems severe enough to cause officials to terminate the


test. A thorough investigation of the causes of the failures resulted in the installation of strengthened first-stage fan blades and adjustments in the turbine providing more cooling for the turbine blades. Even these fixes encountered problems later, however, and it soon became clear that existing propulsion technology simply might not be adequate to meet the specified requirements. At that time, however, the airframe and other components were progressing smoothly toward a November 1974 production deadline, which created enormous pressure to hold Pratt & Whitney to its contractual schedule obligations. The technical problems which had delayed the full qualification of the engine were fully resolved in October 1973, when the engine was declared to have successfully completed the contractually required endurance tests. In reality, the test itself was altered in order to allow the program to continue as planned; pressure for schedule adherence proved to be more important than the original contract provisions. Additional fixes through March of 1974 further enhanced the rigidity of the fan


section,\textsuperscript{107} but durability problems continued to plague the F100 throughout the rest of the decade.\textsuperscript{108}

The complex avionics system was designed so that problems could be quickly fixed on the flight line by removing a defective electronics box or module and substituting a new one. The modules themselves, however, were too large and costly to be discarded or returned to a major depot every time they malfunctioned. The Air Force responded by providing each F-15 unit with an Avionics Intermediate Shop (AIS) where faults could be traced to a specific component within the module. The AIS, however, although essential if the unit were to sustain operations, required four C-141 freighters for transports. This amounted to 25% of the total support requirements for each unit, a tremendous logistics burden.\textsuperscript{109}

The F-15 was the first aircraft to incorporate safety requirements in its contract; as result, it was the first


\textsuperscript{108} An ongoing Component Improvement Program (CIP) resulted, focusing exclusively on the F100 engine, and costing the Air Force nearly $700 million from 1974-1985. Normally, such programs are instituted to improve technology beyond original requirements; in this case, the CIP sought merely to bring the engine up to the standards specified in its original contract. See McNaugher, 1989, pp. 97-99; and David Mondey, "Expanding Capability for the McDonnell Douglas F-15 Eagle," \textit{Jane's Defence Review, Vol. 3, No. 2}, 1982, pp. 155-160.

\textsuperscript{109} See Bill Sweetman, \textit{Advanced Fighter Technology}, 1987.
fighter to achieve its first 5,000 flight hours accident-free. The first F-15 loss occurred on October 15, 1975, by an Air Force pilot at Luke Air Force Base, after 7,500 hours total flying time had been accumulated on 47 F-15 aircraft.\textsuperscript{110}

\textbf{Renewed Pressure for Commonality}

The question of combining the F-15 and F-14 programs, or cancelling one in favor of dual-service use of the other, reopened sporadically throughout the early 1970's.\textsuperscript{111} The first major threat was aimed at overall Pentagon spending policies by a bipartisan group called the Members of Congress for Peace Through Law (MCPL). This 85-member bipartisan group, aiming to cut the FY 1972 defense budget by $7-10 billion, issued a report on the two aircraft in May of 1971.\textsuperscript{112} While the MCPL recommended retaining the F-15 program at previously planned funding levels, the next month a House Appropriations Committee study showing that the F-14 could perform the air superiority mission and therefore permit the F-15 development to be dropped touched off a "massive Air

\begin{itemize}
\item \textsuperscript{110} Stevenson, 1978, p. 29.
\item \textsuperscript{111} See "F-14 Vs. F-15: Will It Come To A Shootout?" \textit{Armed Forces Journal}, 28 February 1970, pp. 20-21.
\end{itemize}
Force reaction." The Committee concluded that, if a choice had to be made between the two aircraft, the F-14 would be the most logical choice because it was about 1 1/2 years ahead in development and could carry out the required missions of both services. Air Force Secretary Robert Seamans responded that the Air Force designed maneuverability and radar into the F-15 which gave it a unique advantage over advanced Soviet aircraft based on Foxbat technology, while the F-14, being designed primarily as a fleet defense interceptor, would not be adequate for Air Force purposes. Air Force Chief of Staff General John Ryan pointed specifically to the F-15's fixed wing as being superior for maneuvering ability and control in air combat. The F-14 has a variable sweep wing. According to Ryan, "To achieve its optimum performance, the wing must be at the correct sweep angle for the specific condition. In the highly dynamic dogfight mode with widely -- and rapidly -- changing air speed, G-load, and altitude, it is much less than certain that the wing will always be at the proper sweep angle, since some time is required to position the wing." Ryan also pointed to the F-15's higher thrust-to-weight ratio and much lower wing loading than the F-14, meaning that throughout virtually the entire flight envelope, the F-15 can


out-turn, out-climb, and out-accelerate the F-14.

The Air Force successfully beat back every Pentagon intrusion on its single-service, single-mission aircraft. As a result, the first F-15 rolled out of the plant in June 1972, and flew a month later. From that time forward, the aircraft met all of its milestones on time, with the exception of the F-100 engine. The engine was late because of technical problems during durability tests. The Category I and II flight test programs were completed with the delivery of the first production F-15 to the Tactical Air Command at Luke Air Force Base on November 14, 1974. On January 9, 1976, the 1st Tactical Fighter Wing at Langley AFB, Virginia, received its first F-15.\textsuperscript{115}

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\textbf{Predictions Revisited: Conclusions About the F-15}
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In sum, this case study finds that, in the early stages of the conceptualization of what would become the F-15, the predictions from the international systems theories seem to be most strongly realized. The U.S Air Force certainly undertook extensive analyses of the threat, particularly of the technical, tactical, and operational challenges presented by past and projected developments in enemy fighters (I-A), and the initial thinking about the F-15 was broadly driven by this technical and tactical (I-D) threat assessment. Difficulties in distinguishing between friend and foe when beyond-visual

range missiles were used, among other lessons from the Vietnam conflict, convinced significant constituencies in the Air Force and the Pentagon that enhanced transonic maneuverability would be the most important feature in the next generation of U.S. fighters.

It took the spark of the July 1967 Domodedovo Air Show in Moscow, however, to pull the various bureaucratic players together at a particular time into a well-defined requirement for a new aircraft. The F-15 did not make its way into the weapons procurement pipeline as a consequence of technological drift or the technological imperative (II-E, II-F). Instead, political and military officials took advantage of technical opportunities created by the weapons laboratories, but only when a specific catalyst from the threat environment dictated that it was time for them to do so (I-C). The FX was transformed in early 1968 into an aircraft with a distinct identity, the F-15, largely because of the tremendous political fervor generated by the unexpected display of the Soviet Union’s new fleet of aircraft.

Very soon after the F-15 became a weapons system with a distinct identity, however, the predictions from the domestic levels of analysis -- bureaucratic and organizational politics -- begin to show more explanatory value. It took an outside threat to ensure that the F-15 would exist, but the specific characteristics of the aircraft seem to have been determined largely due to the Air Force’s overwhelming desire to keep its
prized aircraft a single-service vehicle. The Air Force consistently, in efforts to protect its organizational "turf" against intrusions from the Navy and the Office of the Secretary of Defense (III-B), went to great lengths to argue that the unique requirements for the F-15 would be unsatisfied by any Navy aircraft (specifically the F-14). This line of reasoning prevented the Pentagon, which was pushing for aircraft commonality in order to save money, from forcing the two services to share the same weapon system; it resulted in the choice for an F-15 with a single seat and optimized for the single mission of air superiority. Indeed, the service pressures against commonality were so strong that the Air Force and Navy habitually collaborated to convince the Congressional Armed Services committees that their respective aircraft had been designed for completely different missions and therefore could never be successfully combined into a joint procurement effort. This common front helped each to protect its own core programs. Such behavior, where organizations form coalitions in order to pool resources (in this case political resources) in order to maximize their bargaining position, is predicted by organization theory (III-D).

The F-15 was also shaped, early in its development history, by what later turned out to be egregious overstatements of the capabilities of a rival aircraft, the Soviet MiG-25 Foxbat. The Foxbat's alleged capabilities
became the focus of early discussions on the necessary characteristics of the F-15, once the initial requirement was set; as bureaucratic constituencies became obsessed with the notion that U.S. fighters were unable to match their Soviet counterparts, more and more technologies (in particular, those necessary to enhance the F-15's top speed) were attached to the F-15 requirement. These arguments satisfied not only several hawks in Congress, such as Senator Stuart Symington, but also assuaged some of the concerns of the Air Force faction which had never become completely convinced that maneuverability was the key to future air combat. These political dynamics fall in line with the bureaucratic politics predictions that additional technologies will be tacked on to weapons systems in order to satisfy various constituencies (II-D), that threat assessments will often serve as post facto justifications for bureaucratic interests (II-C), and that weapons systems as a whole are compromise resultants of the meshing of a variety of bureaucratic interests (II-G).

The specific procedures by which the F-15 was developed and produced were clearly selected because of the Pentagon's and Air Force's interest in avoiding a procurement disaster like the F-111. The use of the strict milestone concept, the incorporation of total system performance responsibility clauses, the mapping of the entire engine-inlet interface before first flight, the Blueline Management Information System, and the deliberate use of known technologies whenever
possible were procurement innovations clearly and expressly intended to elude the mistakes of the past. Organization theory, of course, predicts that past failure is one of the few mechanisms which will spur large organizations to innovate (III-E).
Chapter Three:
The "Lightweight" Fighter? The U.S. F-16

Similar to the F-15, initial consideration of the need for what would eventually become the F-16 stemmed from a combination of international systemic and domestic factors -- the latter once again demonstrating how well the Air Force plays the game of organizational politics. In terms of the broad threat environment, lessons learned from recent combat experience were causing U.S. military analysts to consider the possibility that quantity might be as useful as quality in some instances of employment of air power. In terms of domestic politics, the Air Force was prompted to consider the development of its own relatively inexpensive, lightweight aircraft out of concern that the Navy might beat it to the punch.

Once again, however, specific system development did not occur until a specific threat -- in this case, the October 1973 war in the Middle East -- made the requirement seem urgent. Again, in the bottom line analysis, performance norms were dominant. The possibility of overseas sales of a relatively cheap fighter aircraft also prompted American decision makers to develop this aircraft when they did.

Once the aircraft got into the procurement pipeline, it was subject primarily to domestic bureaucratic and organizational dynamics. More advanced technologies than might otherwise have been the case were incorporated into the
F-16 because of the prototyping procurement strategy employed; the prototype competition permitted the effective demonstration of technology which the Air Force might have considered too risky if the source selection had taken place on the basis of paper studies alone. More importantly, however, the evidence indicates that the F-16 became a multi-mission aircraft, much heavier than it would have been otherwise, because the Air Force was anxious to protect its prized F-15 program and did want a new cheap, lightweight, single-mission air-to-air fighter to constitute effective competition to it.

Broad Threat Dictates a New Requirement: The Quantity/Quality Debate

In the years after World War II, American fighter aircraft increased considerably in size and weight. More and more equipment was added as individual aircraft were expected to perform multiple missions. During the 1950's and 1960's, thoughts of a lightweight fighter were lost as the "Century Series" fighters from the F-100 to the F-106 grew heavier and heavier. It took the experience of the Vietnam War, in which light, highly maneuverable Soviet MiG's met with great success, to prove to the relevant constituencies in the United States that the lightweight fighter was a viable concept.

In the late 1960's and early 1970's, those responsible for the overall defense budget recognized the need to reverse
this trend. We have already seen how critical constituencies in favor of a lightweight fighter played a role in the development of the F-15, and how the F-15 emerged as a relatively heavy, compromise aircraft which did not resolve the lightweight fighter debate. Advocacy of lightweight fighters continued; influential members of the aviation community remained convinced that it was unnecessary to penalize aerodynamic performance and operational readiness by designing fighters to carry weighty, sophisticated, and, in their view, ineffective combat aids. The majority of the Air Force, however, still disagreed, remaining convinced of the desirability of extra systems that might make the difference between success and failure in combat.¹

The Air Force Takes Notice: Inter-Service Politics

A crucial first step took place in the spring of 1970, when the "Lightweight Fighter mafia" convinced the Air Force Systems Command to fund small studies by industry and by the Aeronautical Systems Division. Everest Riccioni, who in January of 1970 had become the head of a small development planning office in the Pentagon with the authority to sponsor new designs, was the main catalyst for these studies. Having developed his own careful studies of the relationship between aircraft top speed, complexity, cost, and combat performance,

Riccioni realized that perhaps the only way to get an Air Force lightweight fighter program off the ground was to exploit the dynamics of interservice rivalry. After having confirmed his hunch that the Navy was in the early stages of a low-cost fighter program of its own, he went to the Air Force with the argument that, if the Navy aircraft got into development first, the Air Force might be forced to repeat the experience of the F-4 and buy a Navy-produced plane. The final chart from Riccioni's briefing to the Air Force looked like this:

Unless the US Air Force thoroughly studies high performance austere fighters and is prepared to consider them as a necessary complement to other air superiority aircraft, the US Air Force may be:
A. Outgamed by the Navy (again)
   and/or
B. Outfought by the Russians.

Riccioni later commented, "That got their attention. The Air Force doesn't respond to what the Russians do. It reacts to what the Navy does." There were, of course, additional catalysts for this work: increasing pressures from Congress and the press concerning the costs of the F-14 and F-15 programs, and underemployed aircraft firms' eagerness to develop and demonstrate a small new fighter for the European market.

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3 Fallows, National Defense, p. 102.

4 Hughes, pp. 416-417.
Soon afterward, Northrop and General Dynamics were awarded study contracts worth $100,000 and $150,000, respectively. The work statement for these studies was mission oriented, emphasizing maneuvering in the transonic and lower supersonic ranges; indeed, the requirements called for no maneuvers at speeds above Mach 1.2. Unsolicited industry proposals also began to surface at this time. Lockheed's Advanced Development Projects Division, commonly known as the "Skunk Works," came up with the most prominent of these. In a four-page proposal, the Skunk Works in December 1970 outlined the development of two prototypes of a lightweight fighter called the CL-1200 Lancer for a $35-36 million price tag, with first flight to take place twelve months later. Secretary of the Air Force Robert Seamans had expressed concern that the F-15 was too expensive to build in adequate quantities, and therefore was willing to recommend the CL-1200 proposal favorably to Deputy Secretary of Defense David Packard. Northrop submitted a similar proposal, based on their P-530 Cobra design, around the same time.

The critical added incentive for the lightweight fighter program was the assumption that the cost of an airplane is

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directly proportional to its weight, all other things being equal. A lighter machine would therefore be a less expensive machine. With the cost of the F-15 hovering at around $15 million per copy in 1972, the Department of Defense and the Air Force knew that any new fighter would have to cost significantly less.

When the lightweight fighter program started in 1972, the idea was to engage in a two-year development program and a one-year test program. The intention was to treat the prototypes only as technology demonstrators, to test the advantages of the lightweight fighter and to prove several new design concepts. At the start of the program, the Air Force said it did not have the necessary confidence in the concepts to take them directly into production. The program was instead designed to produce "on-the-shelf" hardware that would let the Air Force eventually develop a new fighter at minimum technical risk. The program was intended to produce a prototype that would use various new concepts and show that they work effectively in practice.

Avoiding Earlier Failures: Prototyping as a Procurement Strategy

Major systems acquisitions of the 1960’s generally followed the practice of concurrent development and production

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carried out under "total package procurement" like that used in the C-5A program. The policy called for an Air Force-directed conceptual design competition phase between contractors, generally on paper only, followed by the selection of one contractor for full-scale development and production. Instead of rendering the weapons acquisition process more efficient, however, this strategy more often than not resulted in inefficiencies and cost overruns.

Seeking to counter these problems, Deputy Secretary of Defense David Packard, a private sector millionaire well-versed in the ways of market competition, decided in the fall of 1971 to reestablish the prototype acquisition concept.8 The Air Force and Department of Defense relied on this procurement concept to keep lightweight fighter costs down and performance deficiencies to a minimum. This approach was very much in fashion in the Department of Defense at the time. Rather than base a decision to go into production on a weapons system on paper studies and designs as had been done on most of the F-16's recent Air Force predecessors, the idea was to build select two different contractors, each of which would build one or more prototypes and test them extensively under operational conditions. Only then would the Air Force and Department of Defense decide whether to go into full-scale production.

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production.

Although more expensive in its initial stages, the prototype approach has several advantages.\(^9\) It gives a better sense of available technical options, and allows proposed costs for the full-scale development and production phases to be better evaluated using actual performance and reliability data. It encourages the introduction of innovative but attainable designs and more realistic system appraisals. In order to realize these advantages, and largely in response to the difficulties with the F-111 and C-5A programs which had been procured under the total package concept, the Department of Defense in 1970 reinstated prototyping as a primary systems acquisition strategy.

In May 1971, Secretary of the Air Force Robert C. Seamans endorsed a recommendation by the Director of Defense Research and Engineering calling for a comprehensive prototype effort.\(^{10}\) This document called for the establishment of a study group to analyze potential management techniques and specific systems for prototyping. The following month, a Prototype Study Group was appointed; its task was to establish a prototype program which would advance technology, reduce technical risks, and ensure low cost options to the government. Deputy Secretary of Defense David Packard asked

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\(^{10}\) Gable, 1987, p. 7.
military leaders to make recommendations for programs they felt should be prototyped, making it clear that the program selected would be used for technology demonstrations only. The Prototype Study Group was asked to evaluate potential candidates and ideas. On 5 August 1971, the Group presented its findings to Packard, recommending the lightweight fighter as one of several possible programs for prototyping. On 26 August 1971, Secretary of Defense Melvin R. Laird issued a program decision memorandum directing the Air Force to establish two competitive lightweight fighter programs. Two days later, Aeronautical Systems Division (ASD) established a Prototype Program Office at Wright-Patterson Air Force Base, Ohio, to manage the lightweight fighter program and other systems approved for prototyping.\footnote{For more detail on the formation of the Prototype Program Office and the LWF program through selection of Northrop and General Dynamics as the competing contractors, see "Flexibility Is Key to Managing Prototypes," Aviation Week and Space Technology, 26 June 1972, pp. 98-101.} Secretary of the Air Force Robert C. Seamans, Jr., prepared a list of ground rules to apply to all potential prototyping projects: existing force structure was not a constraint; there would be a minimum of military specification requirements; funding would be limited; there would be a competition because the system could go into production, although there would be no production commitment; there would be minimum initial performance goals; and the system would be designated "Y" instead of "X" because it would blend off-the-
shelf and experimental technologies.\textsuperscript{12}

In September 1971, the Prototype Program Office prepared project and procurement plans, requests for proposals, source selection plans, and determinations and findings for the lightweight fighter.\textsuperscript{13} At the same time, the Secretary of Defense requested that Air Force Headquarters write a development concept paper (DCP) to address prototype cost, schedules, performance, and testing. This document incorporated a $3 million per unit flyaway cost and emphasized that the objective of the program was to encourage cost consciousness on the part of the contractor and the government.\textsuperscript{14} The flyaway cost goal, however, was never made contractual, since no production commitment was being considered at the time. Since the whole idea of the prototyping strategy was to allow the contractors to experiment with and demonstrate technology freely, the Air Force did not write a Required Operational Capability (ROC). The areas of technical risk to be examined included high acceleration cockpits, sidestick/fly-by-wire control, automatic variable camber, neutral stability, and the flutter, lift, and drag problems associated with high aspect ratio thin wings. The Air Force hoped eventually to use the program to

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\textsuperscript{12} "War Spurred Lightweight Fighter Effort," \textit{Aviation Week and Space Technology}, 2 May 1977, p. 71.
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\textsuperscript{13} Gable, 1987, p. 8.
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\textsuperscript{14} Gable, 1987, p. 11.
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investigate other technically innovative areas as well: composite structures; side force, direct lift, and task oriented control; and integrated stores.\textsuperscript{15} There was no definite intent at this time to develop an operational aircraft immediately after the prototype competition. Instead, the aim was simply to experiment with these new technologies, evaluate them, and then have them available for incorporation into other weapon systems, thus removing many of the technological unknowns which would have been associated with a direct plunge into weapon systems development. The stress at this early stage on development strictly of subsystems and aerodynamic concepts rather than a fully missionized aircraft accounts for Air Force acquiescence to the program; under other circumstances, the program would have been interpreted as potentially threatening the service's prized F-15.

On 31 December 1971, acting Secretary of the Air Force John L. McLucases authorized the release of the requests for proposals to nine airframe contractors. In contrast to past RFP's, the main substance of this document (the statement of work, source selection criteria, etc.) was only ten pages long, and the total was only 54 pages instead of the usual

several hundred. The Statement of Work was only one page, asking the contractors to design, develop, and fabricate two prototypes; certify the flight safety of each aircraft throughout its envelope; conduct a flight-test program to verify the satisfaction of the performance and design requirements; train four Air Force pilots; provide logistics, engineering, and maintenance support throughout the twelve-month testing phase; provide certain data as required; and prepare and submit a final report, including recommendations for follow-on engineering development. Contractor responses were limited to 50 pages of technical information and 10 pages of management data; in past programs, such documents had often amounted to several thousand pages. The bidding companies were also asked to submit wind tunnel models of their proposed LWF design configurations, to be evaluated at the NASA Ames test facilities as a part of the source selection process.

Five companies responded on 18 February 1972: General Dynamics, Boeing, Lockheed, LTV Aerospace, and Northrop. The request for proposals was hailed at the time as "a contractor's dream," allowing considerable latitude for interpreting the very loosely defined specifications. Although the Prototype Study Group had recommended several

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design goals which were included in the RFP, actual design responsibility fell to the contractor.

The design and performance objectives for the prototype aircraft were stated as goals, not as rigid requirements, in order to encourage design tradeoffs. The Prototype Study Group suggested ten such goals for the lightweight fighter prototypes:¹⁹

* Gross weight less than 20,000 pounds;
* Unequalled performance and maneuverability in the transonic high-g arena;
* Combat radii of 225 n mi (internal tanks) to 700 n mi (with external tanks);
* Mach 1-1.2 at sea level and Mach 2 at altitude (with fixed geometry inlets);
* In-being or late development propulsion;
* Mission-essential avionics;
* Representative state-of-the-art high muzzle velocity gun and effective, low-cost air-to-air missile;
* Hardpoints for systems and for credible air-to-ground capability;
* Excellent pilot visibility; and
* Excellent handling qualities.

The goal was an aircraft that could outmaneuver Soviet fighters in the operational region where air combat is actually fought, at altitudes up to 30,000-40,000 feet and speeds of 0.6-1.6 Mach. It was not intended to match the MiG-25 Foxbat, perceived at the time to be a Mach 2.8 interceptor with a service ceiling above 80,000 feet.²⁰

The emphasis was clearly on the demonstration of a basic

¹⁹ "Five Firms To Submit Fighter Proposals," Aviation Week and Space Technology, 14 February 1972, p. 18; and Rand Prototype Study, p. 86.

flight vehicle, not on a fully missionized weapon system. Avionics subsystems were to provide only a minimum capability for communication and navigation during the test period; for armament, only an internal gun, with appropriate sight head, and provision for infrared missiles was specified.\textsuperscript{21} The source selection emphasis would be, however, on evaluating the systems' combat capability and utility, rather than simply assessing the various technical innovations that might be involved.

Recognizing that a large number of contractors had expressed an interest in the lightweight fighter program, the Air Force decided to go with a dual-source prototype structure. The General Dynamics 401 and Northrop P600 lightweight fighter prototype proposals won the prototype source selection. General Dynamics and Northrop were each awarded a contract on 14 April 1972 to build two prototype aircraft, which would then each undergo about 300 hours of testing.\textsuperscript{22} The former chose a single-engine design, designated the YF-16, while the latter's two-engine prototype was dubbed the YF-17. General Dynamics had evaluated a twin-engine design in the early phases of its conceptual effort, but found that studies on twin-engine reliability and survivability were inconclusive; their research determined

\textsuperscript{21} Rand Prototype Study, p. 96.

\textsuperscript{22} For details on the prototype contracts, see Gable, 1987, p. 10.
that a single Pratt & Whitney F100 turbofan with its high bypass ratio provided the best balance of combat capability and mission radius with the lowest weight penalty.\textsuperscript{23} Except for the number of engines, and the fact that the Northrop aircraft was slightly larger, the two winning designs were remarkably similar: little or no emphasis on survivability/vulnerability aspects, short (one year) structure lifetime, no emphasis on producibility or life cycle costs (two items on each had to be hand built on soft tooling), and minimal investments in operational safety features (back-up power supplies, elaborate ejection seat, etc.).

\begin{table}[h]
\centering
\caption{F-16 Prototypes: Physical Description\textsuperscript{24}}
\begin{tabular}{|l|c|c|}
\hline
\textbf{Item} & \textbf{YF-16} & \textbf{YF-17} \\
\hline
Empty weight (lbs) & 13,200 & 17,390 \\
Takeoff gross weight (lbs) & 21,400 & 24,760 \\
Internal fuel weight (lbs) & 6,600 & 6,400 \\
Wing area (sq ft) & 283.5 & 350 \\
Wing span (ft) & 29 & 37.7 \\
Fuselage length (ft) & 46.5 & 55.5 \\
\hline
\textbf{Engine} & & \\
Number & 1 & 2 \\
Type & F100 & J101 \\
Max thrust per engine (lbs) & 24,000 & 15,000 \\
\hline
\end{tabular}
\end{table}

The contractors had started from substantially different reference points in developing the lightweight fighter prototypes. Northrop had been working since about 1965 on the


\textsuperscript{24} Rand Prototype Study, p. 99.
company-funded P-530 Cobra, consistently employing 40-50 people on various advanced design activities and accumulating about 5,000 hours of wind tunnel time exclusively on that aircraft.\textsuperscript{25} That company therefore already had a specific design configured in some detail which they felt was responsive to the LWF RFP, although the aircraft had been initially oriented toward the NATO market and had evolved through several years of direct discussions and negotiations with European nations.\textsuperscript{26}

General Dynamics' work on lightweight fighter designs had begun around 1964. When the F-X concept formulation studies were done in 1966, the company responded with two parallel efforts, one fully responsive to the F-X requirements, the other a smaller, more austere fighter equipped only with a gun. After it lost the F-X/F-15 competition, it maintained a continuous study of LWF alternatives.\textsuperscript{27} A considerable amount of wind tunnel work was performed by a staff of 10-15 people on over 70 different configurations throughout 1968-1970. It is clear that they had not decided on a specific LWF design to the extent that Northrop had in their P-530; General Dynamics did not decide on a single design approach until early 1971.\textsuperscript{28}

\textsuperscript{25} For details, see Donald E. Fink, "YF-17 Evolved From Previous Data Base," Aviation Week and Space Technology, 15 April 1974, pp. 45-51.

\textsuperscript{26} Rand Prototype Study, p. 99.

\textsuperscript{27} Rand Prototype Study, p. 99.

\textsuperscript{28} Rand Prototype Study, pp. 99-100.
Northrop therefore had a more completely defined design concept around which they could build their LWF proposal, but in turn they were more constrained in incorporating new technology without making major changes in their design. This difference in starting points was reflected in the two designs; the YF-16 was somewhat more adventurous in technological content, while the YF-17 was more conventional. In both cases, the substantial amount of information accumulated on the LWF concept before receipt of the prototype RFP is probably one important reason for the success of the prototype phase of LWF development.29

The core of the prototyping philosophy was that the competitors would be put to the test in flights which would simulate what they would see in actual operations. The decision concept paper estimated a one-year test program for both contractors. The General Dynamics test program was to begin in January 1974 with operational evaluation to be completed one year later; the Northrop program was to lag by four months.

The Air Force recognized that successful prototyping would require management practices different from those usually employed in weapon system development. The Prototype Study Group formulated five principles for managing the prototype programs which came to be known as "Adaptive

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29 Rand Prototype Study, p. 100.
Management": 30

* Use small government and industry organizations. The Air Force Program Manager should have maximum responsibility for program decisions.

* Use contractor-formatted data, when data are required, to avoid reformatting costs.

* Minimize controls and program documentation both within industry and government. Emphasize on-site assessment in lieu of contractor documentation. Waive non-essential regulations. Encourage the contractor to simplify his own management techniques.

* Defer both managerial and technical elements not directly related to the prototype program, including configuration management, supporting technical data, and reprocurement data.

* Tailor testing to attainment of specific program goals. Category I, II, and III testing, as required by Air Force regulation, should not be conducted. Instead, the contractor and the Air Force should jointly perform both the air worthiness demonstration and the flight evaluation, with the Air Force entering the program at the earliest possible date.

The initial prototype plans did not officially include production. Regardless of the official plan, however, all of the candidate contractors consistently behaved as though they expected the aircraft eventually to be produced. 31 General Dynamics, for example, began doing production cost studies in late 1973 and working on the programming aspects of production


in early 1974. By early 1974, it had also briefed foreign friendly air forces on the aircraft in a preliminary export marketing effort.

The prototype contracts were a major management innovation in three respects. First, they explicitly waived Military Specification requirements. Both contractors abided by MilSpecs as a matter of course anyway, but the waiver allowed them to avoid extensive compliance documentation. Second, they were cost-reimbursement contracts with a ceiling on the government's obligation, providing the Air Force with two benefits: access to the contractors' records was retained without sacrificing a fixed-price environment, and the Limitation of Government Obligation (LOGO) clause permitted the establishment of yearly funding limits, which is normally not allowed with straight cost-reimbursement contracts. The LOGO clause, while sometimes tricky to apply because of the detailed financial planning required far in advance of the actual work, in this case was used quite successfully because the cost ceilings were not unrealistic and because the potential for lucrative follow-on work prompted the competitors to perform attentively and efficiently. Finally, although the Statement of Work requested the contractors to fabricate two flyable aircraft, they were obligated only to use their "best effort" to achieve program goals. Indeed, the

32 Rand Prototype Study, p. 93.
33 Rand Prototype Study, pp. 89-90.
Air Force explicitly told the bidders that they could satisfy their contractual obligations by "delivering a flatbed of bolts," if that was what represented their best effort using the contractually specified amount of money.\textsuperscript{34} The expectation that the competition would result in follow-on production, however, led General Dynamics and Northrop to devote their talents and material resources quite seriously to the prototyping effort.

The initial Prototype Program Office, established on 27 August 1971, oversaw both the lightweight fighter and other proposed prototype programs. A separate System Program Office (SPO) was not established for the LWF until October 1974, several months after the decision was made to proceed with full-scale development.\textsuperscript{35} The number of people assigned to the LWF program was remarkably relatively low, with only four full-timers as late as January 1974. During the prototype flight testing, the office never employed more than 50-60 people, not counting representatives from Europe. After F-16 selection and the start of full-scale development, however, manning levels grew rapidly.

Communication between the service and the contractors on both engineering and financial matters took place primarily on an informal, one-to-one basis throughout prototype development. This environment was made possible by the

\textsuperscript{34} Rand Prototype Study, p. 89.

\textsuperscript{35} Rand Prototype Study, p. 90.
austere SPO personnel practices, by the minimal contractor reporting requirements, and by the Aeronautical Systems Division instructions to service plant representatives to limit their involvement to safety and quality control issues. In addition, design reviews were conducted incrementally, so that only the technical and managerial personnel responsible for the portion of design being reviewed were required to be present.  

On 13 December 1973, the red, white, and blue YF-16 prototype was rolled out of the hangar at the General Dynamics plant in Fort Worth, Texas. This first F-16 was therefore ready for flight less than two years after the prototype go-ahead decision.  

Several weeks after this initial rollout, the General Dynamics prototype was dismantled enough to fit into a C-5 Galaxy transport and flown to Edwards Air Force Base, California, to begin the flight test portion of the competition. The second YF-16 appeared at Edwards on 27 February 1974, painted in a camouflage pattern of sky blue and cloud white (which would later be found unsatisfactory and replaced with bluish-gray). The two Northrop prototypes rolled out on 9 June and 21 August 1974.

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36 Rand Prototyping Study, p. 90.
Initial Air Force Opposition

At first the Air Force was opposed to whole idea of the Lightweight Fighter concept, fearing that any new fighter program might jeopardize its prized F-15 procurement. Its resistance was broken down considerably when Secretary of Defense James Schlesinger decided to procure an additional five tactical fighter wings; this assured the service that the new aircraft would be bought to complement, not replace, the planned F-15 force.

Competition for limited Air Force RDT&E funds, and potential opposition to the lightweight fighter from staunch F-15 advocates, was muted by Packard's strategy to fund the prototype program separately, out of the budget of the Office of the Secretary of Defense, and not from the services' budgets. The idea was to minimize potential service resistance while maximizing political support for the program. The aircraft was sold to the Air Force as a simple technology demonstrator, or as a complement to the F-15 under the "high-low" force mix concept, and was presented to Congress as an

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38 See Peter R. Foster, F-16 Fighting Falcon, Ian Allen Ltd., London, 1989, p. 3. One commentator goes still further in describing the ongoing tension within the Air Force concerning the F-16's perceived threat to the F-15: "The lightweight fighter concepts were usually proposed as a complement to the F-15 rather than as replacements for it, but the F-15's partisans could read the blunt criticism of their product barely veiled behind these comments. Within the Air Force, loyalty to the F-15 became a profession of faith -- a prerequisite act of belief for all those who seek membership." Fallows, National Defense, p. 103.

39 Rand Prototype Study, p. 87.
experiment in austere competitive development, incorporating the fly-before-buy concept then popular in the legislature.\textsuperscript{40}

While this strategy enabled the program to get off the ground, the effects of the aircraft's exclusion from formal force structure planning channels were not all positive. Neither an operations concept nor a support concept were available, for example, when prototype development started, forcing the systems program office to improvise on decisions relating to those areas. If these concepts had been defined before, or even during, the prototype phase, the contractors could have been doing maintenance- and support-related design refinement studies during the flight test phase in anticipation of full-scale development.\textsuperscript{41} Particularly important was the extent of air-to-ground capability to be built into the aircraft, which would normally have been strongly been influenced by the using command. Instead, Tactical Air Command did not begin to study mission-area related issues seriously until the spring of 1974.

A Specific Threat Catalyzes Requirement Definition: The October War

It was primarily the Middle East war of 1973 which jolted tactical planners into the realization that numbers of fighter


\textsuperscript{41} Rand Prototype Study, p. 87.
aircraft could be as critical as top performance in air superiority battles.\textsuperscript{42} In March 1974, Air Force Chief of Staff General George S. Brown established the Tactical Fighter Modernization Study Group, consisting of representatives from the Air Staff, Air Force Logistics Command, Air Force Systems Command, Tactical Air Command, Pacific Air Forces, and U.S. Air Forces in Europe.\textsuperscript{43} Tasked with developing a tactical fighter force modernization strategy for the 1980's, the group addressed the suitability of potential operational derivatives of the lightweight fighter prototype. After several meetings at Wright-Patterson Air Force Base, the group recommended operational employment of the lightweight fighter in May 1974. As soon as the LWF prototype test flights began, Air Force officials realized that both aircraft offered advanced in air-to-air combat technology even though advanced components and subsystems had been bypassed. According to Lt. Gen. William J. Evans, then the USAF's research and development director, "The aircraft could be missionized and produced cost-effectively as a potent weapons system."\textsuperscript{44} On 11 July of that year, Deputy Secretary of Defense William P. Clements, Jr., announced that the Air Force would do exactly that. Later

\textsuperscript{42} "War Spurred Lightweight Fighter Effort," \textit{Aviation Week and Space Technology}, 2 May 1977, pp. 71-72.

\textsuperscript{43} Gable, 1987, p. 13.

that month, the Air Combat Fighter Transition Program was formally initiated to bring the prototype through full-scale development and procurement.

An additional important influence in the decision to take the aircraft beyond the prototype phase was the potential for overseas sales. In the spring of 1974, Iran expressed interest in buying 250 missionized versions of the Northrop prototype. Of course, the European buy (to be discussed in more retail later) also strongly influenced the pace of source selection and development.

Operationally, the winner of the lightweight fighter competition would fit into the Defense Department’s then-relatively new high-low concept: a "high-cost" McDonnell Douglas F-15 with advanced long-range aircraft/missile capabilities to blunt an initial attack, with "low-cost" lightweight fighters handling a large portion of the remaining close-in threat after the initial encounters. The low-end aircraft was also planned for deployment to relatively low-threat areas where the stand-off capability of the F-15 would not be required.45 The idea was to ensure the retention of the American qualitative advantage (with the F-15) while at least partially offsetting the Soviet/Warsaw Pact quantitative advantage. The F-16 was intended to be especially effective in the visual, close-in maneuvering air combat arena,

complementing the full spectrum capabilities of the F-15. The F-15 has greater top speed than the F-16, more rapid supersonic acceleration, longer range radar, a beyond-visual-range missile kill capability, a greater air-to-air armament payload, and an advantage in maneuvering at high supersonic speeds. It also has a broader systems capability for air-to-air combat and the ability to operate in all weather conditions. The F-16, on the other hand, has slightly better subsonic, transonic, and low supersonic turning performance and a greater radius of action with its design payloads. Its smaller size lends it the tactical advantages associated with small visual and radar signatures.⁴⁶

 Protecting Organizational Missions and Needs: Prototype Testing, Source Selection, and Development

The test program objectives specified in the lightweight fighter decision concept paper were quite general. Each contractor was to hold performance demonstrations to verify the operational flight envelope and provide the opportunity for evaluation of handling properties, airframe and system qualities, armament operations, and operational

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⁴⁶ For exhaustive comparative technical detail on the F-15 and F-16, see Lightweight Fighter Aircraft Program, Hearings before the Senate Committee on Appropriations, 94th Congress, 1st Session, 6 May 1975, pp. 70–91.
characteristics.\textsuperscript{47} For both the YF-16 and YF-17, both contractor and Air Force pilots participated in the flight test program. The Air Force participants were from the Air Force Systems Command, the organization responsible for developing new aircraft, and from the Tactical Air Command, which would be the ultimate user of the aircraft.\textsuperscript{48}

The Air Force flight test crew was broken into three teams. One team flew each contender for about an equal share of flight time, while each of the others concentrated on one aircraft or the other. This composition meant not only that service pilots entered the test program far sooner than in conventional programs, but also that the involvement of operations-oriented pilots began earlier.\textsuperscript{49} During these tests, the aircrafts' operational capabilities were assessed for both the air-to-air and air-to-ground missions. The test pilots had target practice on towed targets, did ground strafing, and participated in simulated air-to-ground missions. They simulated air-to-air combat against other first-line American fighters, including F-4E's.\textsuperscript{50}

Besides evaluating the flight qualities, the aircrafts'

\textsuperscript{47} For details on the prototype flight test programs, see Donald E. Fink, "YF-16 Could Advance Air Combat Tactics," Aviation Week and Space Technology, 21 October 1974, pp. 40-44; and Gable, 1987, pp. 12, 18.

\textsuperscript{48} Siuru and Holder, 1991, pp. 7-8. See also Rand Prototype Study, pp. 92-93.

\textsuperscript{49} Rand Prototype Study, p. 92.

\textsuperscript{50} Siuru and Holder, 1976, p. 69.
maintenance aspects were also tested and evaluated. The Air Force was anxious to buy a plane with both maximum operational utility and minimum total lifetime cost. During the prototype flight test program, about 30 maintenance personnel were on hand: 17 from Tactical Air Command, 10 or 11 from Air Force Logistics Command, and 2 or 3 from Air Force Systems Command. The suggestions garnered from their observations, in particular a modified engine mounting scheme and a substantial reduction in the number of parts used in the aircraft, were incorporated into the full-scale development program.\footnote{51}

Until the aircraft were actually demonstrated, the lightweight fighter concept was poorly understood and not well supported within the Air Force, according to Lt. Gen. James T. Stewart, then commander of the USAF Systems Command's Aeronautical Systems Division. "There was a wide feeling that it would be short-legged, that it couldn't carry anything."\footnote{52} Only when the performance and cost figures were assessed did the service's skepticism subside, and former critics of the program become proponents.

Of course, occasional glitches marred the flight test


\footnote{52} Quoted in "War Spurred Lightweight Fighter Effort," \textit{Aviation Week and Space Technology}, 2 May 1977, p. 71.
program. During a maximum weight takeoff demonstration in September 1974, one F-16 aircraft suffered an engine malfunction. A huge fireball was blown out of the nozzle, and the engine continued to flame as the pilot brought the aircraft to a stop. Neither the aircraft nor engine sustained serious damage. On another occasion, General Dynamics' test pilot Neil Anderson, flying the number two prototype over the General Dynamics facility at Fort Worth, could not get his right landing gear to drop during final approach. After flying around for about a half hour, trying to solve the problem with no success, he made a gentle belly landing without landing gear on the grass to the side of the main runway, skidding about 350 yards before stopping. Again, the pilot was unhurt and remarkably little damage was done to the aircraft.

During later operational testing, addition problems emerged, all of which were identified and solved by the end of 1977. Some of them required retrofits in already-complete production aircraft. The most substantial of these, and their solutions, were:

53 For an account of minor early testing difficulties, not discussed here because they resulted in little to no damage to the aircraft involved and negligible delay in the testing program, see "YF-16 Prototype Resumes Tests; Fuel Control Units Are Studied," Aviation Week and Space Technology, 3 June 1974, p. 20.

54 Siuru and Holder, 1976, p. 70.

55 From testimony by Lt. Gen. Thomas P. Stafford, Deputy Air Force Chief of Staff for Research, Development, and Acquisition, in Department of Defense Authorization for Appropriations for FY 1980,
* Environmental control system (ECS) capability was insufficient for adequate avionics cooling and canopy defogging. Correction: a larger capacity ECS system was installed in all production aircraft, and the ducting system was changed.

* The jet fuel starter did not start the engine consistently. Correction: Starter reliability was improved, and modified starters were installed in all production aircraft.

* Caution and warning lights occasionally illuminated randomly. Correction: Onboard systems monitoring equipment was extensively tested and upgraded.

* Excessively high engine thrust resulted in high taxi speed. Correction: An engine modification was installed to reduce ground idle thrust. The correction was incorporated in all production aircraft.

* Engines lack backup fuel pump and fuel control. Correction: A backup fuel pump is in development, and in the interim, as a result of redesign and improved quality assurance, the reliability of the main fuel pump is satisfactory.

In order to accommodate the 1 January 1975 target completion date for source selection (which, as will be explained later, stemmed from the requirement of the European purchasers of the aircraft), both contractors had to accelerate flight testing. Since the YF-16 prototype had made its first flight four months earlier than its competitor, General Dynamics was not as affected by the acceleration of the flight testing schedule as was Northrop.\(^{56}\) The former completed testing in about nine months because the YF-16 made more flights per month and completed more tests per flight

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\(^{56}\) Gable, 1987, p. 18.
than were called for in its original flight test plan. Northrop had to make major revisions, including a schedule revision in order to get all the testing in by the end of 1974, careful prioritizing of test points, and the addition of more air-to-ground tests. These revisions, which involved a requirement to qualify more pilots, increased Northrop's contract cost by $1.3 million.\textsuperscript{57} The Air National Guard provided the contractor with a tanker to assist the YF-17s' refueling, tripling the number of test points that could be accomplished in each flight.\textsuperscript{58} Northrop's ground-support team used a work schedule of seven days per week, three shifts per day during the accelerated test schedule period. Although the number of flights was not equal (the YF-16 logged about 320, as opposed to about 230 for the YF-17), the amount of data accumulated on each aircraft was said to have been comparable. The schedule compression is not considered to have affected Northrop's prototype program nor to have significantly influenced the source selection.\textsuperscript{59}

**Source Selection**

Once the summer 1974 decision to take the winning prototype into production was announced, both contractors were awarded transition contracts of $4 million each to prepare

\textsuperscript{57} Gable, 1987, p. 18.

\textsuperscript{58} Rand Prototype Study p. 92.

\textsuperscript{59} Rand Prototype Study, pp. 92-93.
their full scale development proposals. They were requested to investigate certain specified design tradeoffs and submit an FSD proposal, a draft vehicle specification, and a draft system specification. This effort was somewhat hectic, since it had to compensate for the informality of the prototype phase; both the contractor and the SPO augmented their staffs considerably as documentation demands increased. This work began only a few months after the flight test programs had begun; in other words, a significant amount of critical full-scale development work took place without the benefit of much of the data eventually to emerge from the flight test program.

The FSD proposals were judged by the following criteria (listed in decreasing order of importance):

1. Operational capability. Assessments of consistency with system specifications, risk, and the potential for reducing continuing operating and support costs.

2. Program cost. Cost proposals were to include development, production, flyaway, operational, and support costs. They were judged on their reasonableness, realism, completeness, and compatibility with design and cost objectives.

3. Prototype/weapon system transition. Extent of the risk associated with any changes required in the prototype aircraft design to make it suitable for quantity production.

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60 Rand Prototype Study, p. 94.

61 For details on this transition period, see Clarence A. Robinson, Jr., "YF-16, YF-17 Production Shifts Studied," Aviation Week and Space Technology, 14 October 1974, pp. 14-16; and Rand Prototype Study, p. 94.

62 Rand Prototype Study, pp. 94-95.
4. Adequacy of program. Soundness and adequacy of proposals for development and integration efforts, taking into account both United States Air Force and multinational aspects.

On the basis of the evaluations and reports of these test pilots, the test force unanimously recommended that the YF-16 was the best of the two fighters to satisfy the Air Force's requirements. The pilots who flew the F-16's were impressed with both its flying characteristics and the creature comforts it provided to the pilot. On 13 January 1975, Air Force Secretary John McLucas announced that the F-16 was the winner of the so-called Air Combat competition, and that F-16 production would commence immediately. General Dynamics was awarded a $417.9 million contract for 15 full scale development aircraft; the contract was similar to most major weapon system FSD contracts in terms of documentation requirements, standard contract clauses, etc.

McLucas commented in his announcement that the YF-16 offered advantages in agility, acceleration, turn rate, and endurance over the YF-17, principally in the transonic and supersonic regime. The aircraft reportedly ran neck and neck in subsonic mission areas; the YF-16's superior performance at higher speeds indicates that it had lower drag.

63 Siuru and Holder, 1976, p. 70.

64 The YF-17 eventually evolved into the Navy's F-18 Hornet; the Navy favors twin-engine aircraft for its carrier-based fighters.

65 Siuru and Holder, 1976, p. 74.
and a cleaner design. Other advantages of the General Dynamics over the Northrop aircraft included better tolerance of high g forces because of the tilt back seat, better visibility, and better acceleration. McLucas also stressed that the contractors' production proposals and overall system costs were also a factor, but that the flight test program was critical in substantiating all the contractors' claims. The YF-16 had lower development, production, and operation support costs by a margin of $1.1 billion, not including the need to develop new engines for the YF-17 (the YF-16 used the F100 engine already deployed on the F-15). In addition, because the YF-17 had two engines, it was estimated that its fuel consumption over a 15-year life cycle would exceed that of the YF-16 to the tune of about $300 million in 1975 dollars.\textsuperscript{66} Air Force naysayers who remained unconvinced of the viability of the basic lightweight fighter concept were pleased that the economies of scale realized through additional F100 production for the F-16 would lower costs for the F-15 as well, making possible additional procurement of the latter.\textsuperscript{67} The flight test procedure apparently was the critical factor in source selection. Although the official source selection proceedings remain classified, one generally accepted assertion is that,

\textsuperscript{66} "F-16 Gains Advantage in Market," \textit{Aviation Week and Space Technology}, 20 January 1975, p. 13. This article also contains additional details on factors leading to the selection of the YF-16.

\textsuperscript{67} Hughes, 1980, pp. 418-419.
if the competition for full-scale development had been held on paper only, the YF-17 would have won simply because few people would have been willing to accept the technical risks inherent in the General Dynamics aircraft. 68 Finally, the selection of the F-16 may have solved a political problem for the Department of Defense, providing General Dynamics with a major, long-term production program at a time when the company’s Fort Worth facility was barely being sustained by tail-end F-111 procurements. 69

General Dynamics was immediately awarded a full-scale development contract for the manufacture of eleven single-seat and four two-seat trainer F-16 aircraft, with associated training, aerospace ground equipment, data, tests, and initial spares. 70 The development contract was a fixed price incentive contract with a target price of $417.9 million, target profit of 11 percent, ceiling price of 130 percent, and a 90/10 share ratio. 71 The YF-17 program was terminated on 31 January 1975, and the next day the Air Combat Fighter Program Office became the F-16 System Program Office at Wright-Patterson Air Force Base. Throughout the early stages of full-scale development, however, the joint test force

continued to fly the YF-16 prototypes in order to identify further necessary changes or refinements in time to include them in the first 15 FSD test aircraft.\textsuperscript{72} The aim was to reduce the possibility that later and hence more costly changes would have to be made in the production aircraft.

\textbf{The Politics of Production}

Even at this late date, Air Force fears for the health of the F-15 program in the face of the cheaper F-16 persisted. General William J. Evans, Air Force Deputy Chief of Staff of the Air Force, testified before Congress in March of 1975 that McDonnell Douglas, the manufacturer of the F-15, had offered to produce additional quantities of that aircraft at a reduced price which would have made them cost competitive with the F-16.\textsuperscript{73} The reduced price, however, was based on a dramatically increased and probably unrealistic rate of procurement, and assumed the provision of government furnished equipment at a price which the Air Force considered too low. The Department of Defense and the Air Force later admitted that Air Force examination of the F-15 proposal was "really being done to

\textsuperscript{72} Donald E. Fink, "YF-16 Tests to Verify Production Design," \textit{Aviation Week and Space Technology}, 3 March 1975, pp. 38-40.

keep General Dynamics' feet to the fire on F-16 costs"; the service remained committed to the high-low mix of F-15's and F-16's. One source claims, however, that even renaming the program "Air Combat Fighter" was an act of spite by a service bureaucracy who took the position that, whatever merit the production F-16 might have, it was no longer going to be "lightweight" and hence constitute a serious threat to the F-15.75

The Air Force has dubbed the F-16 the "Swing Force Fighter" because it can perform equally well in the air-to-air and the air-to-ground role. The aircraft was originally optimized for the air-to-air mission.76 YF-16 Program Director Lyman C. Josephs explained, "We didn't make any compromises, and when designing an airplane for one mission, and it's small and simple, you can really understand the whole program."77 Its high thrust-to-weight ratio and low wing loading, however, gave it the capacity to carry external


76 See Department of Defense Appropriations for 1976, Hearings before the Subcommittee on the Department of Defense, House Committee on Appropriations, Part 2, 94th Congress, 1st Session, 10 March 1975, pp. 84-88, for the Air Force's official statement of the intended roles and missions of the F-15 and F-16 up to that time.

stores, munitions, and fuel tanks, rendering it excellent for air-to-surface support as well.\textsuperscript{78}

The aircraft's shift in mission as the aircraft proceeded from the prototyping phase into full-scale development is apparent in the mission capability and flight vehicle performance goals stated for the operational configuration. While fighter sweep, escort, combat air patrol, and intercept missions are still primary, close air support, interdiction, and nuclear weapons delivery missions are explicitly laid out as well.\textsuperscript{79} "The ACF [Air Combat Fighter] is thus a multi-purpose fighter designed primarily for air superiority with a complementary but extensive air-to-ground capability."\textsuperscript{80} As a result, besides a 20-mm cannon and two wing-tip mounted Sidewinder missiles, nine underwing and ventral hardpoints were added compared with five in the YF-16. Further vehicle configuration changes made necessary by this shift from a pure air-to-air day fighter toward a multipurpose system with air-to-ground capability are illustrated in Table 3.2.

\textsuperscript{78} Siuru and Holder, 1991, p. 55; see also Monahan interview, 1976, pp. 20-21.

\textsuperscript{79} Before leaving the Pentagon in 1975, Secretary of Defense James Schlesinger struck a deal with General David Jones, then Air Force Chief of Staff, that the F-16 would not be assigned nuclear delivery missions. Schlesinger knew that if that happened, the aircraft would be held on strategic alert at its bases, and that pilots would therefore not be able to make the frequent training flights necessary to become competent flying it. Within a week of Schlesinger's departure, the Air Force ordered nuclear equipment for the F-16. See Fallows, National Defense, p. 106.

\textsuperscript{80} Quoted in Rand Prototype Study, p. 110.
Table 3.2
F-16 Changes From the Prototype

- Emergency power unit modified and relocated
- Ejection seat
- F100(3) production engine
  - Improved removal provisions
  - Jet fuel starter
- Resized horizontal tail
- Additional graphite composites
- Added tail hook
- Expanded external stores capability
- Wing area expanded 20 sq. ft.
- 10 in. fuselage extension
- Increased landing gear capability
- Deleted blow-in doors
- Improved access provisions
- Multi-mode radar
- Missionized avionics

Quite a few observers felt as though the changes made to the aircraft as it went into full-scale production defeated the whole purpose of the original plans for a cheap, lightweight fighter. General John D. Ryan, Air Force Chief of Staff during the early phases of the LWF program, for example, observes that "it is not what we intended for it to begin with, but here is a $5 million airplane, but it isn't a $5 million weapon system. By the time you make it into a weapon system, it is going to be a $10 or $11 million airplane, and it still isn't going to have the capability of the F-15."  

Why were these changes made, adding missions and hence capability and weight to the lightweight fighter? As the YF-

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81 Rand Prototype Study, p. 112.

16 proceeded into full-scale development and hence was transformed into the F-16, it was handed over to the Air Force's development and procurement bureaucracies, from which it had been protected until this point. Under General Alton Slay, head of the Air Force's Configuration Control Committee, full-scale engineering development meant redefining the aircraft's mission to include attacking ground targets and dropping nuclear bombs, justifying structural and electronic changes, and modifying the blueprints to add the technical specifications which had been deliberately avoided previously. The added missions loaded roughly two tons of additional avionics and other modifications onto the plane.\textsuperscript{33}

Thus the entire philosophy under which the aircraft had been conceptualized and the prototypes developed was jettisoned. The Air Force and contractor management teams grew from 200 people to about 1,700, and the plane's mission was redefined. The structural and electronic changes justified by the new missions raised the F-16's cost and weight and significantly degraded its performance as an air-to-air fighter, conveniently reducing its status as a potential competitor to the F-15.\textsuperscript{34}

When the full-scale development phase was started, the basic structure design of the YF-16 was retained, but the detail design was completely redone to much narrower margins


(the YF-16 structure was deliberately overdesigned by a stress margin of about 25% so that high-stress flight maneuvers could be performed without extensive static proof tests of the basic structure). The contractor stated that not a single part was interchangeable between the prototype and the FSD aircraft. The 10-inch increase in fuselage length and 20 square foot increase in wing area also required some redesign, the degree of which is illustrated by the comparison of the two versions in Table 3.3.

Table 3.3
Weight Comparison, YF-16 to F-16A

<table>
<thead>
<tr>
<th>Item</th>
<th>YF-16</th>
<th>F-16</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structures group</td>
<td>6507</td>
<td>7180</td>
</tr>
<tr>
<td>Propulsion group</td>
<td>3395</td>
<td>3671</td>
</tr>
<tr>
<td>Fixed equipment group</td>
<td>3415</td>
<td>3860</td>
</tr>
<tr>
<td>Weight empty</td>
<td>13295</td>
<td>14738</td>
</tr>
<tr>
<td>Useful load (crew, etc.)</td>
<td>1418</td>
<td>961</td>
</tr>
<tr>
<td>Payload (munitions)</td>
<td>605</td>
<td>619</td>
</tr>
<tr>
<td>Zero-fuel weight</td>
<td>15318</td>
<td>16318</td>
</tr>
<tr>
<td>Full internal fuel</td>
<td>6511</td>
<td>6775</td>
</tr>
<tr>
<td>Combat weight</td>
<td></td>
<td></td>
</tr>
<tr>
<td>External tanks</td>
<td>0</td>
<td>880</td>
</tr>
<tr>
<td>External fuel</td>
<td>0</td>
<td>4810</td>
</tr>
<tr>
<td>Takeoff gross weight</td>
<td>21829</td>
<td>28783</td>
</tr>
</tbody>
</table>

Placing the F-16 in the hands of the Air Force, however, did ensure its single-service integrity. In the late autumn of 1975, a Congressional proposal surfaced to consolidate the F-16 and the Navy/McDonnell Douglas F-18 with the aim of eventually procuring a single air combat fighter for both

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86 Rand Prototype Study, p. 108.
services. Both services vociferously defended the unique requirements of their respective aircraft, repeatedly invoking the failure of the F-111 to accomplish commonality goals successfully, and the idea soon fizzled.

Some analysts continue to argue that the Air Force kept the F-16 deliberately spartan until the F-15 production run was essentially complete, and then proceeded to load it with complex and heavy electronics and payload capacity. The service defended itself with claims of a rational response to a changing threat. In answer to a question about the addition of the AIM-7F Sparrow missile to the F-16 rather late in the production program, for example, the Air Force countered that the initial austere configuration of the F-16 appeared to meet the threat as it was envisioned at the time, but as the Warsaw Pact developed an increased all-weather radar/missile capability, there was a need to equip the F-16 with a similar

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88 Some sources, perhaps of questionable reliability, also maintained that the Air Force deliberately painted the F-16 with an air-to-ground camouflage color and spent the majority of early F-16 operational activity on air-to-ground missions in order to divert attention away from the aircraft's air-to-air prowess -- and hence to protect the F-15. See Jim Stevenson, "TAC Tries New Warpaint On F-16," Defense Week, 28 July 1980, pp. 4-6; and "TAC Brass Try Pep Talks To Boost F-16 Pilots' Morale," Defense Week, 6 October 1980, p. 5.
Indeed, the F-16 was becoming so heavy and costly at this point that the old McDonnell Douglas proposal to fill out the fighter force with additional F-15's instead of F-16's resurfaced.\textsuperscript{90} The Air Force was becoming concerned about Soviet fighters with enhanced beyond-visual-range capability coming on line, and about the F-16's inability to counter that threat. One Air Force official summarized the problem: "They could place F-16's in their missile launch envelopes long before the F-16's could fire on them."\textsuperscript{91} These arguments were quickly squelched, however, when the F-16 began to defeat the F-15 in early 1980 preliminary semi-official head-to-head air-to-air test engagements. F-16 pilots at the time claimed that their small size alone allowed them to see the F-15's first, offsetting the latter's more powerful radar to "jump and outmaneuver" it.\textsuperscript{92}


\textsuperscript{91} "Fighter Force Structure Mix Scrutinized," \textit{Aviation Week and Space Technology}, 11 February 1980, p. 20.

The European Market

The F-16 represented General Dynamics', and the United States', initial step into the fighter aircraft markets in Europe and the rest of the world. The late 1970's was seen as a time of ripe markets, with many of NATO's front-line second-generation jets nearing the end of their service lives. In 1969, the Defense Ministers of the European NATO countries had established the Eurogroup to discuss and coordinate plans for new European weapons systems. At its December 1973 meeting, the group passed a resolution urging Belgium, Denmark, the Netherlands, and Norway, all of whom were in the market for a new fighter, to coordinate their efforts to select a new aircraft. In early 1974, these four countries formed the European Multi-National Fighter Programme Group (MFPG) to evaluate candidates for a possible joint fighter aircraft procurement program to replace their F-104. Aircraft under consideration were the F-16, the Northrop Cobra, the French Mirage F1, and the Saab JA-37 Viggen. No one at the time doubted that the F-15 could accomplish the missions required by the MFPG, but there simply was not enough money to handle its price tag.\(^3\)

\(^3\) Foster, 1989, p. 6.

The United States government took a keen interest in this European activity. In February 1974, Secretary of State Henry Kissinger told the defense ministers of the MFPG countries that, if they selected an American aircraft, the United States government would collaborate to expedite the development of certain aircraft components, support the transfer of aircraft technologies evolved through collaborative research and development, provide logistical support for the European program equal to that given to American aircraft, and consider complementing and supporting U.S. industrial offset proposals under terms and conditions to be mutually agreed.\(^5\) Throughout early 1974, U.S. government officials kept the NATO allies informed of progress in the lightweight fighter program and assured them of the U.S. commitment to produce the fighter eventually.

On 27 April 1974, Secretary of Defense James Schlesinger wrote a letter to the Congressional Armed Services and Appropriations Committees outlining DoD's intentions to take the lightweight fighter into full-scale development in fiscal year 1975. When the NATO defense ministers held a summit meeting several days later in Brussels, their copy of this letter was a major topic of discussion. At that time, they agreed to the following:

* No nation would make a unilateral decision on a next-generation fighter without further consultation;

\(^5\) Gable, 1987, p. 35.
* A joint military steering group would be formed to continue fact-finding on candidate aircraft and to report weekly to the ministers of defense;

* Representatives of the four nations would visit France on 3 June 1974, and the United States three weeks later, to get firsthand views of the prospective aircraft and proposals;

* Belgium would postpone its planned June 1974 decision until September;

* The joint steering committee would set forth professional and technical recommendations for the replacement aircraft without regard for the political aspects of the decision; and

* The United States would be requested to guarantee a minimum number of aircraft to be produced.

On 20 May 1974, the steering committee formally invited the governments of France and the United States to submit bids for the common purchase of 384 fighters: 116 for Belgium, 102 for the Netherlands, 72 for Norway, and 58 for Denmark. At that time, the Europeans wanted the United States to commit by the end of the next month to eventual production in quantity for the U.S. inventory of one of the lightweight fighter prototypes, to guarantee the fighter’s deployment to Europe, and to accelerate the prototype source selection, which was then scheduled for April 1975.

By that time, Denmark, Norway, and the Netherlands had decided to purchase the winner of the lightweight fighter competition, but Belgian officials remained undecided. On 2 June 1974, Belgian Defense Minister Paul Vanden Boeynants and American Secretary of Defense Schlesinger met to discuss

program details. Schlesinger renewed an expired not-to-exceed offer of $6.091 million per aircraft (based on a 1,000 aircraft program), and three weeks later, Deputy Secretary of Defense Clements agreed to the full-scale development and production of the lightweight fighter, and to its deployment in Europe. At the same time, Aeronautical Systems Division Commander General James Stewart agreed to shorten the prototype competition by three months, resulting in a source selection decision in January 1975.97

The MFFG officially selected the F-16 at the Paris Air Show in early June 1975, signing a Memorandum of Understanding (MOU) on 10 June setting forth the conditions of European participation in the program, and preliminary bilateral contracts outlining each country's aircraft requirements, financial agreements, and schedules.98 Apparently the fighter's dramatic demonstrations at La Bourget were a major factor in the Europeans' selection.99 The Europeans had four goals in mind: to acquire a low-cost aircraft with advanced avionics and weapons capability; to standardize NATO aircraft; to share American technology; and to make optimum use of European industrial, economic, and technical resources during


the production process. The Americans apparently were anxious to drum up business for their depressed aerospace industry; to achieve some degree of weapons standardization within NATO; and most of all, to make a dent in a balance of payments problem estimated at the time at as much as $3 billion. In September 1975, a European System Program Office was established in Brussels, assigned to support the coproduction effort in Europe and to support the buildup of the logistics framework for the aircraft among the participating European countries.

The MOU contained multinational agreements on the conduct of the full-scale development program, the sharing of non-recurring development costs, total aircraft quantities to be procured, costs, and offsets. It stipulated that the United States would be responsible for full-scale development of the aircraft, and that the Europeans would reimburse the United States government at a rate of $470,000 per FSD aircraft for non-recurring development costs. This recoupment fee was structured such that, if a total of 2,000 aircraft were

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100 Gable, 1987, p. 43.


102 Monahan interview, p. 1; for further details, see Herbert J. Coleman, "F-16 Team Forming in Europe," Aviation Week and Space Technology, 16 June 1975, pp. 16-18.

purchased by the United States, the European consortium, and third parties, the United States would recoup all research and development costs; calculating the cost benefits a different way, the European buy alone reduced the unit cost of F-16 production by about $140,000 per aircraft.\textsuperscript{104} The European governments financed their own production programs individually, but they agreed to pay a share of any non-recurring costs applicable to production aircraft. Individual governments were responsible for funding any production-peculiar changes they chose to make in isolation. Finally, the MOU contained a 40-10-15 offset agreement to assure European participation in the production program; European industry produced 40% of the value of the European buy, 10% of the value of the U.S. buy, and 15% of the value of future sales to other countries.\textsuperscript{105} This arrangement guaranteed European manufacturers 58% of the 348 aircraft purchased by the four European countries and held the possibility of further industrial opportunities if more countries elected to buy F-16's. Industries of each country in the consortium participated in the fabrication, mating, and assembly of the aircraft, with production occurring simultaneously in Europe.


\textsuperscript{105} Gable, 1987, p. 39.
and the United States. Companies in all five countries produced engine components, airplane equipment, and avionics systems; the European manufacturers of airframe parts and assemblies were Fairey and S.A.B.C.A. in Belgium and Fokker-VFW in the Netherlands; and European final assembly, testing, and delivery took place at S.A.B.C.A. and Fokker.

Coproduction programs such as that for the F-16 involve complex cost calculations. An early study of available cost data on the F-16 showed that the United States would pay anywhere from $70 to $241 million more to coproduce the first 650 F-16's than would have been the case for completely domestic production because of higher European production costs and inflation rates and the use of multiple production lines. Another study, while concurring with these estimates of increased costs, also pointed out that the United States would realize as much as $369 million in economic benefits over the same production run because of recouped research and development costs, shared production overheads, and increased production volume in the United States. At the time, the United States government certainly was of the view that the F-16 coproduction program promised a favorable cost outcome for the United States.107

The F-16 coproduction program had a marked impact on the pace of the aircraft development and procurement program.

106 Gable, 1987, p. 41.
First of all, it forced an early delivery requirement; Dutch and Belgian demands for early replacement of their aging F-104G aircraft accelerated the program. Second, it resulted in start-up delays due to the need to resolve differences in acquisition procedures, find qualified European contractors, and negotiate the division of labor.\textsuperscript{108} Finally, it led to longer lead times because of European work force policies discouraging surges in labor. These longer lead times pushed the United States toward an earlier production decision than would have been the case otherwise, causing considerable development and production concurrency. Also, the differences in lead times impeded incorporation of changes and complicated scheduling for final assembly.\textsuperscript{109}

Development and Production Strategies

The F-16 incorporated several innovative aerodynamic design concepts.\textsuperscript{110} The blended wing/body concept not only saves weight but increases the overall lift at high angles of attack and reduces drag in the transonic speed range. Movable

\textsuperscript{108} See Monahan interview, 1976, pp. 8-9.

\textsuperscript{109} Gable, 1987, p. 42.

flaps on the forty-degree swept-back wing leading and trailing edges, controlled automatically by the aircraft's speed and altitude, enable the wing to assume an optimum configuration under all flight conditions. Highly-swept strakes leading forward along the nose provide further lift, prevent wing-root stall, reduce buffeting, and improve directional stability and roll control. The air inlet was ventrally situated, leading to economy of both construction and weight, and positioned forward of the landing gear to avoid the danger of stones being ingested during taxi and takeoff.

The F-16 is constructed of lightweight, but not highly exotic, materials. Its structure is 80% duralumin (an aluminum derivative), a material that probably would not have been used extensively if cost considerations were not such a predominant factor. More expensive titanium and composite materials comprise less than 10% of the airframe; they were used only where absolutely necessary to do the job.\textsuperscript{111} This is one area in which the prototype testing program provided critical information; the YF-17 had made extensive use of composites on doors and access panels, with unacceptable results. Fasteners pulled through, edges frayed and caught on the clothing of maintenance people, and the weight savings were small.\textsuperscript{112} Identical and interchangeable parts, including the tail surfaces, ventral fins, and flap/ailerons, were

\textsuperscript{111} Siuru and Holder, 1991, p. 16.

\textsuperscript{112} Rand Prototype Study, p. 107.
another cost-saving aspect of the F-16 design. Eighty percent of the landing gear is also interchangeable from the port to starboard sic.\textsuperscript{113}

The F-16 uses a fly-by-wire control system, replacing the normal mechanical linkages, cables, and bellcranks with electrical wires to carry the pilot’s commands from his control panels and devices to the individual actuators that actually move the control surfaces. The electrical system, which was a breakthrough in technology at the time, offers better handling qualities, more precise and responsive control, increased reliability and survivability, and a more simplified aircraft structure leaving more room for fuel, than its mechanical predecessor. The F-16 contains no mechanical backup for the wire-controlled system, but four separate channels for the electrical signals ensure safety through redundancy.\textsuperscript{114}

Another unique feature of the F-16’s control system is its relaxed static stability.\textsuperscript{115} A conventional aircraft is designed with the center of gravity forward, so that aerodynamics and inertial forces tend to make it go in the direction in which the nose is pointed. When a maneuver is required in the pitch plane, some of the control power must be

\textsuperscript{113} Siuru and Holder, 1991, p. 16.

\textsuperscript{114} Siuru and Holder, 1991, p. 19.

\textsuperscript{115} For more details on the technical aspects of relaxed static stability, see Rand Prototype Study, p. 101.
used to overcome this built-in stability. The F-16 was therefore designed to be slightly unstable at subsonic speeds, and the flight control system was tasked with making the aircraft behave properly. Although this concept had existed in theory for years, this was the first time it had been put into practice.

Cost considerations were a high priority throughout production.\footnote{See "Plants in U.S., Europe Gear Up for Huge Task of Producing a Fighter," The Wall Street Journal, 6 February 1976, pp. 1, 16, for details on early contractor devotion to cost considerations. For details on cost-saving design and production techniques throughout the program, see Erwin J. Bulban, "Studies Pinpoint Cost-Saving F-16 Manufacturing Techniques," Aviation Week and Space Technology, 2 May 1977, pp. 81-91.} Single parts were adopted for multiple uses, lowering tooling/fabrication and logistics/support costs. Only 50 different types of fasteners were used, for example, while 150-250 types are typically used in other aircraft.\footnote{Siuru and Holder, 1991, p. 21.} The stress on modular design permits ease of manufacturing, technology upgrading, adaptation to other requirements, and multinational participation in production.\footnote{These design techniques also improve reliability and maintainability, which were stressed early in the F-16 program. See "Reliability Emphasized Earlier in Design," Aviation Week and Space Technology, 6 October 1980, pp. 71-76; and Chester A. Hardy, "The F-16: A Successful Effort To Contain Logistic Support Costs," Defense Management Journal, First Quarter 1984, pp. 8-15.} Existing equipment was also used wherever possible. Of the aircraft's original 373 equipment components, 57 were new developments, but 59 were modifications of other aircraft equipment, and 257
came straight "off the shelf."\textsuperscript{119} \n
The Air Force also made a deliberate decision to incorporate a relatively austere radar system on the F-16.\textsuperscript{120} Air cooled, as opposed to the liquid-cooling on that of the F-15, the F-16 radar has only 30\% the number of parts of the F-15 radar and is roughly twice as reliable. Again, this decision was made primarily out of consideration for procurement and life cycle costs.\textsuperscript{121} The F-16 equipment is optimized for the vast majority of the air combat envelope, but cannot handle high-altitude, high-speed threats as can the F-15. This is consistent with the F-16 design philosophy; the F-16 was intended for air-to-air engagements only at lower speeds (below Mach 1.5) and lower altitudes.

Perhaps the most dramatic cost-saving decision related to the F-16, however, was the decision to use the same Pratt and Whitney F100 afterburning turbofan engine that powers the F-15. The costly process of developing and testing a new engine was avoided. Engine commonality also saved millions of dollars in training of maintenance personnel, the cost of specialized maintenance tools, and in the number of spare

\textsuperscript{119} Siuru and Holder, 1991, p. 21.

\textsuperscript{120} For additional technical detail, see "Versatility, Cost Keys to Radar Choice," \textit{Aviation Week and Space Technology}, 2 May 1977, pp. 127-128.

\textsuperscript{121} Thurman, testimony before the Senate Armed Services Committee FY 1976 Procurement Hearings, pp. 4564-4605.
parts that have to be kept in the supply inventory.\textsuperscript{122} Although the F100 embodied highly advanced technology at the time (and indeed did experience earlier development difficulties), by the time it was adopted for the F-16, it was a fully mature engine, having accumulated over 2000 engine flight hours in the F-15 test program.

The remainder of the F-16 incorporates a number of advanced technologies and design innovations which had not previously been incorporated into a single aircraft, which is not a surprise for an aircraft originally intended to be a technology demonstrator. Quite a unique philosophy governed the use of advanced technologies in the F-16, however. The incorporation of advanced technology usually means an increase in aircraft cost and complexity. In the F-16, particular technologies were selected and integrated in such a manner that they actually decreased the overall weight of the plane by thousands of pounds, leading to a reduction in the cost of aircraft development and production.\textsuperscript{123}

Due the requirement for high maneuverability, special attention was given to the design of the cockpit. The seat angle is laid back 30 degrees; sitting in a reclined position greatly increases the pilot's tolerance to high g's, allows him to track targets better, and improves his view to the

\textsuperscript{122} Siuru and Holder, 1976, p. 21.

\textsuperscript{123} Siuru and Holder, 1976, pp. 31, 35.
rear. To further aid the pilot under stress conditions, the F-16 control stick is mounted on the right side of the cockpit and requires very little movement for full control; as opposed to then-conventional sticks mounted on the cockpit floor and extending up between the pilot’s legs, the side stick cleans up the cockpit and saves some weight. The F-16 is also equipped with a bubble canopy that allows the pilot almost unlimited visibility: 360 degrees in the horizontal direction, 260 degrees side to side, 195 degrees fore and aft, 40 degrees down over the side, and 15 degrees over the nose. The canopy is fabricated from polycarbonate, a virtually indestructible plastic.

Beginning in mid-1980, a complex Multi-Staged Improvement Program (MSIP) was initiated for the F-16, loading even more complex electronics and armaments, most notably an AMRAAM missile and the LANTIRN night-attack bombing navigation system. The initial proponents of the lightweight fighter

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124 Siuru and Holder, 1976, p. 36.
125 Gable, 1987, p. 22.
126 Siuru and Holder, 1991, p. 22. The YF-17 had incorporated a conventional two-piece canopy, with the forward part fixed, a conventional seat, and a conventional control system with conventional mechanical linkages to the control surfaces. See Rand Prototype Study, pp. 100-101.
concept were, and remain, dismayed. John Boyd saw the MSIP as something that would "wreck the airplane."\textsuperscript{128}

In October 1976, General Dynamics conducted a rollout ceremony for the first full-scale development F-16; after two months of flight testing, the Air Force accepted delivery of the aircraft. On 7 December 1977, Deputy Secretary of Defense Charles W. Duncan gave final approval for full-scale production and release of FY 1978 production funds. Although production had been approved, full-scale development tests continued until early 1979.\textsuperscript{129} There was considerable concern over the concurrency of the phases, since several technical problems still existed in 1977. If major problems arose after the production start, a major retrofit program would have been necessary.

The radar was considered the highest risk program. As of March 1977, the radar subcontractor was two months behind schedule, and it appeared that F-16 production would have to start before the completion of this major subsystem development. The problems centered around a high false alarm rate, the detection range, and the Doppler beam sharpening map.\textsuperscript{130} After an Air Force design review team declared these problems "solvable," on 11 July 1977 service officials


\textsuperscript{129} Gable, 1987, p. 32.

\textsuperscript{130} Gable, 1987, p. 32.
accepted the avionics test aircraft with a waiver against "total radar performance."\textsuperscript{131}

Significant problems, however, still hampered the development of the F100 engine. When deployed on the F-15, the engine had experienced problems with stall-stagnation, turbine blade containment, and control reliability, forcing several modifications.\textsuperscript{132} Finally, there were difficulties with the half-inch production-coated canopy. In February 1977, engineers at Arnold Engineering Development Center identified two failure modes: the production-coated canopy could not withstand bird strikes at certain speeds, and uncoated canopies were insufficiently rigid. Air Force and General Dynamics Engineers solved these problems by changing to a three-quarter inch canopy coated with a new material, Texstar 254-1C.\textsuperscript{133}

The first production F-16 was delivered and accepted on 17 August 1978, and the first delivery to an operational unit followed soon after on 6 January 1979.\textsuperscript{134} Reliability and maintainability (R&M) tests were conducted on the full-scale development and first three production F-16's through March 1979. Officials pronounced the aircraft fully combat-capable and supportable, with the mean time between maintenance at

\textsuperscript{131} Gable, 1987, p. 32.
\textsuperscript{132} Gable, 1987, pp. 32-33.
\textsuperscript{133} Gable, 1987, p. 33.
\textsuperscript{134} Foster, 1989, p. 6.
0.83 hours and operational mission reliability 83 percent.  
In October 1979, the full-scale development program was completed, although one additional configuration change took place in 1980 with a 30 percent increase in the area of the horizontal tail in order to improve handling and performance in the cruise configuration.  
The F-16 fleet achieved IOC in October 1980, when the 4th Tactical Fighter Squadron, 388th Tactical Fighter Wing, Hill AFB, Utah, passed its first Operational Readiness Inspection (ORI).  

Predictions Revisited: Conclusions About the F-16  
In sum, this case study finds that early conceptualization and development of the F-16 took place for a variety of reasons: the realization of the Lightweight Fighter Mafia that larger numbers of cheaper, lighter aircraft were the most rational means of response to the current and unfolding threat environment (I-A, I-C), and the Air Force's panic not to be "left behind" the Navy in the trend toward developing such an aircraft (III-B). The F-16 case is a potent argument against theories of technological determinism and the technological imperative (II-E, II-F), since the aircraft was originally intended to serve only as a technology demonstrator, and indeed remained just that until the  

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136 Gable, 1987, p. 34.  
137 Gable, 1987, p. 34.
experience of the 1973 October War in the Middle East jolted tactical planners into the realization that numbers of fighters could be as critical as top performance in air superiority engagements. In other words, the F-16's transition from technology demonstrator prototype to an aircraft definitely intended for operational employment took place, and in particular took place when it did, because of careful analyses of the technical, tactical, and operational challenges presented by the threat environment (I-A, I-C).

Indeed, there had been strong pressure from the Air Force before October 1973 not to proceed with operational conceptualization and development of the F-16 because of the fear that a cheaper but still effective aircraft would present a threat to the service's prized F-15; the Air Force, as always, was obsessed with protecting its core program (III-B). The Office of the Secretary of Defense smartly protected its own interests throughout the prototyping phase of the F-16's development by keeping control over its operations and resources to itself, thus preventing Air Force opposition from perveting the program. This strategy was in keeping with the organization theory tenet that control of weapons system choices and outcomes accrues to those actors who dictate the allocation of resources (III-C).

Once the prototype selection was made, however, and the F-16 became an Air Force program, the Secretary of Defense's fears were realized. The service added additional missions,
resulting in substantial extra weight, which had been previously deliberately avoided; the initial philosophy of the lightweight fighter was seriously diluted. Once again, the Air Force was protecting the F-15 from a potential competitor, behaving as predicted to rally around what it defined as its core program (III-B, II-D).

As was the case with the F-15, the prototyping procurement strategy was explicitly chosen in order to minimize the chances of repeating past procurement disasters, specifically that of the F-111. The Pentagon exhibited innovative behavior in order to prevent a recurrence of previous failure (III-E). The choice of the prototyping strategy had dramatic implications for the eventual shape of the F-16, since it permitted designers to take technological risks they might not have otherwise; in fact, if the competition for full-scale development had been held on paper only, the YF-17 probably would have been chosen because few people would have been willing to accept the technical risks inherent in the YF-16.
Chapter Four:
The Skunk Works Achieve Stealth: The U.S. F-117

The first steps toward the F-117 were taken because of a combination of international systemic and domestic factors: a broad threat environment that called for the development of stealth capability, and the progress of technological development that would realize such capability. Even though the technological capacity for stealth had existed for several years, however, it was not until the experience of the October 1973 war in the Middle East that the specific requirement was formulated for the Stealth Fighter, and the formal development program initiated -- again, a process dominated by performance norms.

The fact that the F-117 was a top secret program insulated it from the types of organizational and bureaucratic maneuverings that characterize the development of the other American fighters. The secrecy, and the fact that the program was relatively small, permitted the contractor to take technological risks and hence develop capabilities that might otherwise not have been possible. Once the program reached near maturity and became known to a larger number of people, it did become influenced by domestic politics. A confluence of legislative support for the program resulted in the production of more aircraft than the Air Force really needed, forcing the service to search for additional missions to which the F-117 could be applied.
Broad Threat Dictates a New Requirement: Stealth

The need for a stealth attack aircraft was initially borne out of the experience of the air war in Vietnam, where one of the major problems was losses of aircraft to radar-guided guns and surface-to-air missiles. By 1972, fewer than half of the aircraft in a Linebacker strike against North Vietnam carried weapons devoted to strikes against primary targets; the rest were support aircraft designed to thwart enemy air defenses (jammers, Wild Weasel defense suppression aircraft, and chaff-bombers).\(^1\) Even though some factions in the Air Force remained convinced that chaff, jamming, and air defense suppression could do the job, the sheer number of SAM's fired by the North Vietnamese managed occasionally to overwhelm the electronic warfare effort.

The Soviet attention to SAM development was troublesome. The Soviets were developing and deploying new systems in ever-growing numbers, and were mounting more recent models on tracked vehicles so that they would be harder to map than they had been in Vietnam. The October 1973 war between Israel and Egypt even further highlighted the need for a drastic new technical or tactical development in the ongoing struggle between air offense and air defense. Egypt's use of the new Soviet SA-6 missile, with its new and improved tracking radar, rendered Israel's jamming equipment ineffective. Israel

incurred heavy losses in the air and on the ground because its assumed air superiority was not achieved. The U.S. Air Force carefully noted the electronic warfare lessons learned from the October War: there is always a risk of surprise in the war between electronic offense and defense, and surprise is very costly. Stealth promised to offer the advantage of being relatively little affected by changes in frequency and waveform, and therefore being immune to those surprises inherent in electronic warfare techniques.

Early Technology Development

Traditional aircraft designs center around aerodynamics and propulsion systems, with electronics receiving relatively low priority. Because of the threat from hostile air defense environments, engineers and military planners of the early and mid-1970's began to reverse this assumption, seeing a role for aircraft less visible to radar, or with a reduced radar cross-section. Radar energy generates an electromagnetic field around an aircraft, in essence making the entire aircraft behave as an antenna. A stealth aircraft designer's task is therefore to design a very bad antenna that can fly.²

The Air Force itself had a low-budget stealth program, primarily grown out of work done by Dr. Leo Windecker, a Texas designer who developed a high-efficiency, all-composite light

plane called the Eagle in the 1960's. The Eagle had a high radar cross-section due to its internal metallic components, but Windecker realized the aircraft's stealth potential and proposed such to the Pentagon as early as 1963. The proposal met with little interest at that time, but after improved results from some years of flying the prototype, Windecker tried again. In 1972, the Air Force awarded him a contract for a specially-designed, low-RCS prototype designated the YE-5A. It was built in the same tooling as the Eagle, but used various absorbers and other RCS-reduction techniques. The YE-5A was delivered to the Air Force in 1973, and was tested by the service, Lockheed, and later the Army in various classified programs. A number of companies, including Northrop, Boeing, and General Dynamics, were also engaged in studies of low observables in the mid-1970's.

A Specific Threat Catalyzes Requirement Definition: The October War

It was not until after the October War, however, that DARPA in 1974 started a program called Harvey, in which five companies were invited to participate in a competition to design a low-observable fighter aircraft. Since Lockheed was not in the fighter business at that time, it did not receive

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4 Sweetman, 1987, p. 60.
an invitation; Ben Rich, head of Advanced Development Projects (ADP, also known as the famed "Skunk Works") at Lockheed, persuaded the Central Intelligence Agency to allow him to reveal some of the work his company had been doing in that same area and participate in the competition.\(^5\) In 1975, the United States Air Force convened the first Radar Camouflage Symposium at Wright-Patterson Air Force Base;\(^6\) although its results remain classified, the very fact of the seminar indicates at least preliminary official Air Force interest in stealth technologies at that time.

Lockheed and Northrop were the preliminary winners of the Harvey program. Each designed competitive prototypes with DARPA funding in late 1975 and early 1976, primarily oriented toward radar cross-section testing.\(^7\) Both companies' full-scale models were tested at the Air Force's Radar Scatter Range (RATSCAT). It was Bill Schroeder and Dennis Overholser,


\(^{6}\) Sweetman and Goodall, 1990, p. 18.

\(^{7}\) "Northrop's 1976 Stealth Fighter Proposal Featured Faceted Body With Overhead Inlet," Aviation Week and Space Technology, 10 February 1992, p. 23. The aviation press at the time incorrectly (as far as is now known) asserted that McDonnell Douglas was also awarded a contract at this time. See "Industry Observer," Aviation Week and Space Technology, 23 June 1975, p. 9.
however, two Skunk Works engineers, who in 1975 developed the winning stealth aircraft design and the computer software necessary to model the design's radar cross section.\(^8\) Northrop's 1975 project eventually led to the B-2 Stealth bomber.\(^9\)

**Soviet Engineering Theory Provides a Boost**

The engineering concept critical to the basic F-117 airframe design was called "faceting," resulting in an aircraft with no curved surfaces except for small-radius, straight edges to its wings and tail surfaces.\(^10\) Faceting works by replacing curved surfaces, which scatter radar energy equally over a wide arc (where it can be readily detected by enemy receivers), with planes and edges, which reflect in a controlled and predictable manner. Flat facets will not reflect a radar emission back to its receiver unless the incoming beam is perpendicular to the surface of the facet, and aircraft designers can align the facets so that 99.9% of

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\(^8\) Sweetman and Goodall, 1990, pp. 19–20.


\(^10\) One of the most accessible discussions of low-observable aircraft technology is Jay H. Goldberg, "The Technology of Stealth," *Technology Review*, Vol. 92, No. 4, May–June 1989, pp. 33–40. Faceting is now considered an early generation stealth technique, and has not been used in the B-2 and Advanced Tactical Fighter.
the reflected radar energy is scattered elsewhere.\textsuperscript{11}

Lockheed designers credit a Soviet scientific paper for giving a substantial boost to their efforts to analyze radar signatures mathematically. Soviet scientist Pyotr Ufimtsev published "Method of Edge Waves in the Physical Theory of Diffraction" in 1962; the United States Air Force translated the work in 1971.\textsuperscript{12} Ufimtsev's method of calculating radar reflections proved to be much more workable than prior Western methods, and according to Alan Brown, chief designer of the F-117, "Made a 30-40% contribution to" the computer programs used to design the aircraft. Designers at the time referred to Ufimtsev's work as an "industrial strength" theory, because it was so broadly applicable.\textsuperscript{13} Schroeder and Overholser's work at Lockheed was based on Ufimtsev's equations. Prior to this breakthrough, the Harvey program had not been considered important even to be highly classified; it was included in the government's regular Commerce Business Digest listings.\textsuperscript{14}

Two methods other than faceting were also employed to reduce the radar cross-section of the F-117. The use of radar-absorbing materials lessens reflected radar energy, and Lockheed also devised techniques to keep the aircraft's

\textsuperscript{11} Goodall, 1991, p. 4. See also Sweetman and Goodall, 1990, pp. 31-32.

\textsuperscript{12} "Lockheed Credits Soviet Theory In Design of F-117," Aviation Week and Space Technology, 16/23 December 1991, p. 27.


\textsuperscript{14} Sweetman, Interavia, p. 28.
infrared signature to a minimum.\textsuperscript{15} The exhaust gases, for example, are mixed with relatively cool ambient air in a plenum just off the engine compartment. This cooling air arrives through ducts located in front of and below the intakes. The cooled exhaust is then passed through a horizontal slot-type nozzle assembly divided into twelve separate ports which channel the gases into an extended lower lip which is actually the flattened empennage of the aircraft. There the exhaust gases are again mixed rapidly with ambient air. By the time the gases enter the aircraft slipstream, their temperature has been lowered significantly and the exhaust plume therefore presents a minimal infrared target.

With these technologies in hand, the Lockheed Skunk Works began to design an operational stealth combat aircraft, virtually undetectable by radar or infrared means, and capable of carrying a useful weapons payload over a useful range. Lockheed outlined a "technology demonstration" program intended to prove the viability of both the basic technologies and the operational aircraft. Rich convinced DARPA to fund the demonstrator program in 1976; the contract was issued in 1977, code named Have Blue. The cornerstones of the Have Blue program were two 60% scale prototypes of the aircraft, each weighing about 1/3 as much as the eventual production

aircraft, and using many off-the-shelf parts to save money—landing gear from the F-5, an environmental control system from the Lockheed C-130, the ejection seat and brakes from the F-15, the Lear Sigler fly-by-wire system from the F-16, and General Electric F85 engines from the F-5 and Cessna A-37B light attack aircraft. The aircraft, because of its decidedly non-aerodynamic design, is inherently unstable, requiring a quadraredundant fly-by-wire system. According to Rich, "Once I had the flight control system, I could make anything fly. Fly-by-wire was the secret to stealth. It freed up the configuration." Design and construction of these two small-scale prototypes cost about $35 million.

The Have Blue program headquarters was transferred from DARPA to the Air Force Systems Command and Wright-Patterson Air Force Base in Dayton, Ohio for security reasons in 1977, and construction of the prototypes proceeded rapidly throughout that year at Lockheed-Burbank. The planes were

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16 See Goodall, 1991, p. 4; Sweetman and Goodall, 1990, p. 20; and "Pentagon Reveals F-117A Costs, Photos; Upgrades Are Under Way at Palmdale," Aviation Week and Space Technology, 9 April 1990, pp. 19-20. The production aircraft used many of the same off-the-shelf parts, including a General Electric F404 engine which, except for the lack of afterburner, is quite similar to that on the McDonnell Douglas F/A-18 strike fighter.


19 The perceived need for greater security might have stemmed from press releases confirming the existence of Lockheed's stealth technology demonstrator aircraft. See "Industry Observer," Aviation Week and Space Technology, 20 June 1977, p. 11. For more
hand-built on quickly-adjustable fixtures; as soon as pieces were designed on paper, the drawings were passed down to the shop and the parts were fabricated.\footnote{Sweetman and Goodall, 1990, p. 21.} The plan was to demonstrate basic flying qualities on the first aircraft, and low observable (Stealth) qualities on the second. The only known glitch in the prototype design and construction came just before Christmas 1977, just before the completion of the first Have Blue aircraft, when Lockheed workers went on strike. Supervisors and managers stepped in as mechanics, and the first prototype was completed and transferred to the Air Force testing facility at Groom Lake, Nevada, in January or February 1978. The test results were sufficiently successful to prompt William Perry, Undersecretary of Defense for Research and Engineering, to give the go-ahead for development and production of a full-size, operational Lockheed stealth strike aircraft, code named Senior Trend, in November 1978.

**Threat Events Further Define Operational Requirements**

The Air Force’s operational requirements for the aircraft were greatly affected by the threat environment at the time. The October War had triggered OPEC’s use of the oil weapon, focusing American political and military leaders’ minds on the strategic situation in the Middle East. Scenarios in which

\footnote{Details on Have Blue design and construction, see Steve Pace, *F-117A Stealth Fighter*, TAB/Aero Books, Blue Ridge Summit, PA, 1992.}
fundamentalist revolutionaries took power in one or more Middle Eastern country, possibly with the aid of a Soviet Union worried about its own Islamic minorities, led to a stress on special operations forces which could use concealment and covert infiltration to overcome the problems of distance to the region, political issues of whether the threatened friendly regimes would ask for help in time, and political sensitivity over any United States involvement in the region at all. These special forces' missions would include counterinsurgency, sabotage of military installations, and hostage rescues. Stealth attack aircraft would be ideal to support these kinds of missions, or even to carry out such missions alone, without being shot down and perhaps without observers knowing whether an American aircraft had been there at all. Stealth aircraft ideally would also be able to hover around long enough to deliver payload accurately and with little collateral damage.

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22 Some confusion remains over the aircraft's designation as an "F," or fighter, aircraft, when it clearly is designed for "A," or attack, missions, and over the fact that the aircraft is numbered "117," when "19" was the next number in the fighter series at the time. Steve Paulson, one of the original program test pilots, weakly justifies the first point by pointing out that the aircraft has some air-to-air capability, although pilots were not trained for air-to-air missions. He does a better job of explaining the numbering. Apparently the number "117" has been traditionally used as a generic term for all new aircraft which have not yet been named, and so that's what the stealth attack aircraft was called at first. When Lockheed printed the first pilot manual for the aircraft, it put the name "F-117" on the cover, and it stuck because the Air Force did not want to spend the money to redo the manuals. Without this error, according to
The Senior Trend aircraft was therefore defined as a single-seat night strike fighter (stealth capability does not imply a Star Trek-style cloaking device; the aircraft is visible to the naked eye in daylight), with no radar (active radar would reveal the existence of the aircraft) but a comprehensive electro-optical aiming system. It also had no need, and therefore no operational requirement, for air-to-air capability; if it found itself facing enemy fighters, its entire purpose would have been defeated. The heavy emphasis was placed on making the aircraft totally autonomous, totally passive, and as elusive a target as technically possible; it would not be dependent on external communications of any kind in order to fulfill its missions. The Air Force envisioned Senior Trend being used singly or in pairs against a small range of targets within a small, carefully-defined range of circumstances. This meant that not many of the aircraft would ever be needed; the initial order, including the five aircraft which would be used for most of the testing, consisted of around 20 aircraft, or a full squadron.

Although most aspects of the development program remain

Paulson, the aircraft probably would have been the F-19. See Goodall interview with Paulson, Goodall, 1991, pp. 19, 23.

23 The F-117's minimal air-to-air capability against airborne early warning and control aircraft was recently declassified, but clearly this capability is not applicable to its primary missions. An F-117 air-to-air mission would probably need assistance from an AWACS or other system. See "F-117 Has Air Combat Ability," Jane's Defence Weekly, 22 February 1992, p. 276.

24 Sweetman and Goodall, 1990, p. 25.
classified, Lockheed engineers have revealed that the most challenging part of the avionics unit to develop was the infrared acquisition and detection system (IRADS). The avionics suite was a whole was initially driven by a need to use existing systems as much as possible, minimizing development risk and costs. Off-the-shelf hardware was used wherever possible and modified where possible, and new hardware was developed only when necessary. As a consequence of this development philosophy, the full-scale development-phase cockpit was composed of F/A-18 multi-function cathode-ray tubes, head-up display, stick grip and throttles mixed with components from practically every aircraft Lockheed had built since the T-33. Parts were taken from the SR-71, P-3, C-130, L-1011, and F-104. The avionics architecture, a distributed real-time processing system, originally used three Delco P62 computers from the F-16. For its inertial navigation system, Lockheed used a Honeywell SPN-GEANS system originally developed for the B-52G/H; by hand-picking specially calibrated units, Lockheed was able to achieve and maintain better than a 0.12 nm/h drift rate throughout the list of the aircraft.

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25 See William Scott, "F-117A Design Presented Avionics Challenges," Aviation Week and Space Technology, 8 February 1993, pp. 43-44.


Built by Texas Instruments, an off-the-shelf single turret IRADS was converted to a twin-turret system consisting of a forward-looking infrared (Flir) and a downward-looking IR (Dlr) sensor package. Each was housed in its own turret and conformed to the aircraft's external contours. The two-turret design was dictated by stealth concerns. The infrared system had to scan from just above the horizon to well behind the aircraft while not disrupting the exterior's faceted surfaces. The dual IR design presented a number of challenging technical problems, such as having the invert the Dlr image and mesh it into a seamless cockpit display. Avionics technical difficulties prompted the formation of a "tiger team," headed by the Skunk Works' chief scientist, who augmented the F-117A group with talent and manpower from other areas of the company. Operating as a major program within the F-117A project, the tiger team still required about one year and 100 test sorties to resolve most of the IRADS problems.

Another difficult technical problem was the design of the flat afterbody portion of the airframe, called the platypus. Heat from the exhaust kept causing the platypus to deform, damaging its precisely faceted shape. Eventually Henry Combs, a Lockheed structures expert, solved the problem with a redesigned shingled structure which accommodated thermal expansion by allowing the panels to slide over one another.

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28 Scott, 8 February 1993, p. 43.
29 Sweetman and Goodall, 1990, p. 29.
Lockheed test pilot Harold (Hal) Farley flew the first full-sized stealth attack aircraft at Groom Lake on 18 June 1981. The four remaining full-scale development aircraft were airborne by early 1982. The development and production program was highly concurrent, with no testing before production in quantity; instead, the decision was made to bring the aircraft into service in the shortest possible time. Lockheed had cut metal on nearly all the initial batch of aircraft before the F-117 made it first flight. The Air Force allowed less than five years between the go-ahead decision for development until initial operation capability. This degree of concurrency can be disastrous, of course, if problems emerge during testing and result in major modifications to aircraft already fielded or far along in the production process, but the F-117 emerged relatively trouble-free, having been delivered on time and near their target price of about $50 million per copy.\(^{30}\) Lockheed's contract included warranties covering the aircraft's range, weapons delivery accuracy, and radar cross section.\(^{31}\) By mid-1982, only one year after the first flight, the stealth attack aircraft was being flown not only by Lockheed and Air Force test pilots, but by Air Force pilots destined for the operational 4450th Tactical Group.


Protecting Organizational Missions and Needs: The Skunk Works Management Style

Much of the credit for the success of the F-117 procurement program is generally directed toward the management style of the Lockheed Skunk Works. Kelly Johnson founded the Skunk Works in 1943, when the P-80 Shooting Star aircraft was being developed. The Army Air Corps asked Lockheed in July 1943 to design a fighter around a particular British engine, and negotiated an agreement with Johnson stipulating that the aircraft had to be delivered within 180 days. Given a free hand by Lockheed's president, Johnson "begged, borrowed, and stole" engineers and technicians from Lockheed's other wartime projects to form a team of 23 engineers and 103 shop mechanics. Their work space was a small assembly shed near the wind tunnel in Burbank, which provided secrecy as well as quick access to the tunnel for tests. Working ten hours a day and six days a week, the Skunk Works completed Lulu Belle, the P-80 prototype, in just 143 days -- 37 days under schedule. Johnson's organization


33 The now-famous moniker is reported to have come from a conversation in which one of Johnson's engineers was asked what was going on in this assembly shed. The engineer replied that Johnson was stirring up some kind of brew, which brought to mind the mysterious, never-seen factory in Al Capp's "Li'l Abner" comic strip which the hillbilly characters called the "skonk works." According to Rich, "since we don't speak hillbilly in California, we became just the Skunk Works." See Rich, 15 November 1988, p. 88.
and management style remained intact and became institutionalized as the Advanced Development Projects went on in the immediate post-war years to build mostly prototypes which, if successful, were then turned over to the white world for production. In 1954, the Skunk Works began work on the U-2 project, which caused it to integrate full-scale manufacturing facilities. It retained these facilities for the whole line of Blackbird reconnaissance aircraft, the A-12, YF-12, and SR-71. Throughout these projects, and throughout the development and production of the F-117, the Skunk Works method, outlined by Johnson in the early 1950’s specifically for that organization, was assiduously followed. Lockheed people say the mark left by Johnson, who retired in 1975, is indelible, and that Rich continues to adhere to his principles designed to streamline operations, assure accountability for each aircraft specification and each management decision, and keep workers communicating rapidly and directly.  

34 Johnson wrote these fourteen rules codify that method:

1. The head of the Skunk Works must have practically complete control of his program in all aspects.

2. The military and industry must provide small but strong project offices.

3. Restrict the number of people having any connection with the project.


4. Simple drawing and release systems with great flexibility for making changes must be provided.

5. Require a minimum number of reports, but record all important work thoroughly.

6. There must be a monthly cost review covering not only what has been spent and committed, but also projected costs to the conclusion of the program.

7. The contractor must be delegated and must assume more than normal responsibility to get good vendor bids for subcontracts.

8. The Skunk Works’ inspection system, which is approved by both the Air Force and the Navy, should be used for all projects. This system centers on nonintrusive and nonduplicative inspections.

9. The contractor must be delegated the authority to test his final product in flight.

10. The specifications applying to the hardware must be agreed to in advance of contracting.

11. Funding a program must be timely so that the contractor doesn’t have to keep running to the bank to support government projects.

12. There must be mutual trust between the military projects organization and the contractor.

13. Access by outsiders to the project and its personnel must be strictly controlled by appropriate security measures.

14. Because only a few people will be used in engineering and most other areas, you must provide ways to reward good performance by pay not based on the number of personnel supervised.

Rich outlines a set of managerial tenets of his own, which serve primarily to demonstrate the degree to which the Skunk Works philosophy has become institutionalized: leadership, teamwork, delegation, management by charisma, practicality, tight scheduling, demand for results, strict
ethics, rewards and punishments, and enjoyment of work.\textsuperscript{36}

It is estimated that the size of the work force for any Skunk Works project runs a mere 7\% to 25\% of that for a similar, nonclassified program at Lockheed. Rich believes that the Skunk Works style, designed to encourage creativity and "maverick" behavior, works best with small groups and on small programs, such as prototypes or short production runs of 50 units or less. In small groups, Rich argues, people get to know one another, making them more likely to speak comfortably with one another and trade information freely.\textsuperscript{37} With such staffing restrictions, one person is often forced to do several jobs; according to the Johnson/Rich philosophy, the pressures of time and a small work force can led people to "produce to near ultimate capability."\textsuperscript{38}

In addition, Rich points out, small programs usually don't cost billions of dollars, and therefore won't break a company if they fail. As a result, companies are willing to take risks with smaller programs that they couldn't with billion-dollar projects, and Rich firmly believes that "it's taking risks that moves companies and technologies forward."\textsuperscript{39}

Program secrecy is also essential for successful risk-taking;

\textsuperscript{36} Rich, 15 November 1988, pp. 92-93.


\textsuperscript{38} Harns, p. 14.

\textsuperscript{39} Rich, 15 November 1988, p. 87.
several F-117 program setbacks, particularly the aircraft crashes during testing, would probably not have been tolerated in the "white world," but such risks are necessary when pushing the outer envelope of technology. Bureaucratic red tape is also not a problem in a small, Skunk Works-type program. Workers and managers alike can deal with individuals, not departments, and problems can be resolved face-to-face in a matter of days rather than weeks or months.

Clearly these managerial tenets were followed in the F-117 program. As Ben Rich remarked at the final F-117 delivery ceremony on 12 July 1990, the number of people involved in the program was kept to a minimum. Prior to the final program go-ahead, five dedicated air staff officers reporting to Air Force Chief of Staff General Alton Slay clearly defined a set of top-level requirements for the aircraft. At the proper time, a system program office (SPO) was established at Aeronautical Systems Division, under the direction of the late General Dave Englund, along with a small parallel team at Lockheed under Norm Nelson.

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40 Two test aircraft crashed in 1986 and 1987; for details, see William B. Scott, "F-117A Crash Reports Cite Pilot Fatigue, Disorientation," *Aviation Week and Space Technology*, 15 May 1989, pp. 22-23. The crashes, each of which were fatal to the pilots, have been primarily attributed to pilot disorientation due to fatigue. For an account of the physical and psychological stress on pilots during classified night flight testing, see Bill Sweetman, "Flying the Black Jet," *Interavia Aerospace Review*, March 1992, pp. 71-74.

41 See Miller, 1991, p. 29, for the text of Rich's speech.
Some of the reasons for the success of the F-117, within the framework of the Skunk Works management rules, according to Rich, were the fact that no new major facilities were built; that Lockheed built the aircraft using aluminum for the basic structure and then introduced graphic thermoplastic structures later on a retrofit basis; that the company used off-the-shelf avionics initially and introduced proven top-of-the-line systems later; that it built the prototypes with soft tooling and then created master tooling and hard tooling for production; and that it used the same type of team approach to avoid adversarial relations with subcontractors. Rich also cites a willingness to forego that last increment of technical capability if the cost is too great. "We can do 90 percent of what you want for 60 percent of the coat. The 40 percent of your cost is the last 10 percent, which you never use. I never use the last 100 pounds of fuel. I never use the last 5 pounds of weight." The best is the enemy of the better, according to Rich.\(^\text{42}\)


Testing and Production

Initial operating capability was declared in October 1983, after the first batch of 20 aircraft was close to complete and a dozen aircraft were operational with the 4450th at Tonopah Test Range. The test program both there and at Groom Lake proceeded with startling success. The aircraft developed the capability to strike such targets as bunkers, which do not radiate heat and might be buried under inconspicuous landmarks, with many of the test flights taking place against active threat radars, including samples of Soviet SA-2, SA-3, and SA-6 systems that Israel had captured from Egyptian forces during the 1973 war.\textsuperscript{45} One test pilot recalls that it quickly became the norm to "pick the hard things because the normal targets were easy."\textsuperscript{46} The test program confirmed the potential operational value of radar cross section reduction; the aircraft was essentially undetectable by any airborne radar in the world except the Boeing E-3 AWACS, and even that only at very close ranges. Most ground-based missile tracking radars could not pick up the aircraft until it was well inside the missile's minimum range, and missile on-board guidance radars could not lock on to the aircraft.\textsuperscript{47}

\textsuperscript{45} Miller, 1991, p. 8.

\textsuperscript{46} Sweetman and Goodall, 1990, p. 77. See also Goodall, 1991, p. 5.

\textsuperscript{47} Goodall, 1991, p. 5.
Meanwhile, the program began to attract support from Congress as more and more people were told of its existence and success. In fact, the support was "more than the Air Force had bargained for."\textsuperscript{48} Conservatives in Congress backed it for obvious reasons, as did the more moderate military reformers because of its creative use of high technology, its utility in situations other than all-out conventional or nuclear war, and its incredible bombing accuracy. Congress directed the Air Force to acquire an entire wing of the aircraft, which generally consists of four squadrons and 72 aircraft. The production line at Lockheed-Burbank kept moving, and two more squadrons were formed at Tonopah.\textsuperscript{49} The Air Force was therefore challenged with the task of finding a mission for this large force of F-117's they were directed to buy. The 20 aircraft which had been initially ordered were more than enough to ensure that an adequate number would be fully mission-ready at any one time for the individual, covert strikes for which the aircraft had been designed; no one originally envisioned using any more than ten aircraft, at most, for any given mission.\textsuperscript{50} Apparently, a secret, high-level debate ensued over the F-117's role, with the result that Congressional plans for the aircraft were scaled back; eventually, 59 of the aircraft were built.

\textsuperscript{48} Sweetman and Goodall, 1990, p. 70.

\textsuperscript{49} Sweetman and Goodall, 1990, p. 70.

\textsuperscript{50} Sweetman and Goodall, 1990, p. 83.
As the operational force grew to dozens of aircraft, the security-oriented restrictions on day flying and use of bases other than Tonopah became a serious hindrance to operations. The aircraft could not train with other forces in combined exercises. It was therefore almost impossible for commanders to write the aircraft into war plans, since they had no direct experience with the aircraft's capabilities. More importantly, night flying was causing incredible pilot fatigue and accidents. The veil of secrecy was therefore lifted from the program in November 1988, resulting in a more complete integration of the aircraft with other assets and an intensification of daytime operations by the 4450th Tactical Group.\footnote{See John D. Morrocco, "USAF Unveils Stealth Fighter; Black Weapons Probe Likely," \textit{Aviation Week and Space Technology}, 14 November 1988, pp. 26-27.} By the spring of 1989, F-117's were operating almost 24 hours a day from Tonopah.\footnote{Sweetman and Goodall, 1990, pp. 87-88.}

\textbf{Predictions Revisited: Conclusions About the F-117}

The F-117 case study is the most potent argument presented in this work against theories of technological determinism and the technological imperative (II-E, II-F). Stealth technologies had been known to the Air Force for a decade before the 1973 October War, but rather than a pattern in which technological developments "bubbled up" from research laboratories to be automatically incorporated into operational
requirements for a weapons system, in this case the technology was only realized after political and military officials had identified a threat to which that technology could respond (I-B). Extensive analyses of the lessons of the October War demonstrated that the war between electronic air offense and defense might always be full of unwelcome surprises, exemplified by recent Soviet surface-to-air missile developments fielded by its client states (I-A, I-C, I-D); stealth technology offered the promise of immunity to those surprises so that command of the air could be ensured in the most vital of circumstances.

Because of the still-sensitive nature of the aircraft's technologies, less is known about the nuts and bolts of the F-117's procurement process than of the other American aircraft studied here. Interesting observations can, however, be made about the organizational environment within which the F-117 procurement took place. Unlike more "traditional" large organizations, which organization theory observes are inherently conservative and tend to adhere strongly to routine behaviors (III-A), the Skunk Works has adopted an organizational philosophy quite the opposite. Indeed, it is possible to characterize the Skunk Works' organizational essence as deliberately, inherently innovative; it is an exceptional organization because its "standard operating procedures" are designed to spur innovation, and it would define conservative behaviors as failures. As a consequence
of this unique organizational philosophy, the F-117 designers were permitted to take technological and managerial risks which would have been impossible in a different context. The ability to take these risks most certainly had a critical impact on the aircraft’s eventual technical and tactical attributes. Indeed, with the stealth fighter, the Skunk Works’ management philosophy enabled it to produce successfully a low radar-cross-section aircraft which responded beautifully to the expressed needs of the Air Force. It seems reasonable to speculate that the classified nature of the program, about which even key members of Congress were not informed until it was well into the latter stages of its development, insulated it from the impact of the domestic organizational and bureaucratic factors felt so strongly by the F-15 and the F-16.

The number of stealth fighters which were eventually built is a classic example of bureaucratic compromise. As the shadow of secrecy was gradually removed from the aircraft, more and more bureaucratic factions came to identify themselves with the aircraft (II-A), leading to the comical situation in which the Air Force had to scramble to find additional missions for the increased number of F-117’s it was directed to buy. The fifty-nine aircraft built were a political resultant, a compromise that satisfied the varying needs of a variety of different players (II-F).
Chapter Five:  
Whither the Soviet Threat? The U.S. F-22

Like the other American aircraft studied here, the F-22 evolved initially because of a broad sense of a new threat, this time from a new generation of Soviet fighter development. Unlike the other aircraft, however, there was no international systemic catalyst to provide the spark for a specific systems requirement to coalesce at a particular time; instead, simple technology availability and the need to sustain defense sector research and production capacity seem to have been the primary drivers. In other words, in the post-Cold War period, American weapons procurement is moving away from adherence to performance norms, perhaps toward a more technonational focus involving nurturance.

Once the F-22 system entered the procurement pipeline, however, it was subjected to a set of domestic political pressures remarkably similar to those surrounding the other American aircraft: the Air Force's strategy to minimize procurement risks so that the program would not fall prey to political criticism, and the concomitant desire to protect the F-22 program from joint development with the Navy and from other potential replacement programs that could jeopardize its survival. In particular, the Air Force has indicated a willingness recently to incorporate air-to-ground capability in the F-22 (when earlier it had fought so hard to preserve a single-mission focus) in order to protect it from new
competitors in response to lessons learned from the Persian Gulf war.

Broad Threat Dictates a New Requirement: New Soviet Systems

American fighters passing over the Ramenskoye airfield north of Moscow discovered a series of new Soviet fighters under development in 1978. The RAM-L, which eventually became the MiG-29, and the RAM-K, which evolved into the Su-27, were the focus of Western concern. If the MiG-29 entered service as a one-to-one replacement for the MiG-21, and the Su-27 similarly for the MiG-23, analysts feared that the Soviets would have duplicated the American high/low fighter mix, but with their low equivalent to our high.\(^1\) Air Force planners were concerned not only with the sheer numbers of these new Soviet aircraft, but with their quality. Soviet advances in airborne radar technology (leading to a lockdown/shootdown fire control capability), air-to-air missile technology, maneuverability, and acceleration rendered the MiG-29 and the Su-27 equal in many respects to the F-15 and F-16, according to most analysts.\(^2\) In addition, Soviet lockdown/shootdown capability would end the American fighters' ability to exploit the low-altitude environment.

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Western air forces were similarly concerned with the growing Soviet arsenal of surface-to-air missiles. By the late 1970's, the Warsaw Pact had developed a SAM network sufficient to constitute a barrier; although it was not impenetrable, it was assumed that it would cause major attrition of NATO aircraft in the opening hours of hostilities.

The notion of a stealth requirement was borne of the observation that recent-generation Soviet fighters carried large, powerful radars and long-range, radar-guided missiles; clearly, low observability was not one of their priorities. The Soviets instead apparently intended to use radar, missile, and maneuverability improvements to achieve a first-look, first-shoot advantage over an opponent. Any stealth capability incorporated into the ATF would turn this development into a handicap, decreasing the range over which Soviet fighters could detect and track a target.\(^3\)

Tension and instability in the Middle East added yet another dimension to air planners' problems. The F-15 had been designed to operate in the European theater; possible allied bases in the Middle East were considerably farther from likely areas of engagement. Assistance from tankers and in-flight refueling would therefore be necessary to perform any mission in that region of growing strategic importance.

Looking at the fighter road map in the late 1970's, it became apparent to the Air Force that both the F-15 and F-16 were young designs with plenty of room for upgrading. The most pressing need was therefore for more long-range interdiction aircraft.\(^4\) Technical, managerial, and political problems had cut the planned buy of F-111's more than in half, and most of those would be more than 20 years old by 1990.\(^5\)

**Early Technology Development**

Since the late 1970's, the Air Force had funded work in various aircraft technologies in order to keep the technology base alive and expanding between major programs.\(^6\) This approach, Air Force planners felt, would allow time for unexpected problems to emerge and alternative solutions to be generated. It also allowed for maturation of specific subsystems before their attempted incorporation into missionized developmental aircraft. The service was anxious to avoid repeating the mistakes of the F-111, and the F100 engine for the F-15.\(^7\) Using modified versions of existing

\(^4\) Sweetman, 1991, p. 11.


\(^7\) See Dave Griffiths, "ATF Team Seeks To Avoid Past Fighter Mistakes," *Defense Week*, 26 April 1992, pp. 4, 11.
aircraft, or new aircraft with off-the-shelf parts, these early demonstrator programs generated generic, widely-applicable technologies. The programs most relevant here were the following:

* the Advanced Fighter Technology Integration (AFTI)/F-16, in which a programmable, digital fly-by-wire system was installed on a prototype F-16, together with two large fins projecting downward and outward from the forward fuselage. The most important objective was to demonstrate innovative methods of controlling the flight of an aircraft in combat.

* the AFTI/F-111, which incorporated a mission-adaptive wing which would change shape, or camber, during flight for better cruise range and maneuverability. Internal mechanisms regulated the contour of the wing, so that the traditional mechanisms of flaps or ailerons were not necessary.

* the Grumman X-29, which was a forward-swept wing demonstrator. Dating back to the mid-1970's, the goal of the forward-swept wing is to achieve sustained maneuverability.

In addition, early in 1983, the Air Force issued an RFP for a STOL demonstrator which would combine speed and maneuverability with the ability to take off and land on 1,500-foot runways. McDonnell Douglas won the $118 million contract to build the F-15 STOL/Maneuver Technology

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Demonstrator (SMTD) in December 1984. The final relevant demonstrator, incorporating stealth technologies, was either never built or remains classified. Although it was discussed in 1982, it is possible that the project never got off the ground because it was overtaken by the ATF itself, or because of manufacturers' fears that the company winning this demonstrator contract would have an overwhelming edge in the contest for the ATF.  

Mission Definition Driven by Technology Availability

In 1979, the Air Force clearly was still thinking in terms of an interdiction aircraft. Early that year, the Air Force's Aeronautical Systems Division had planned to solicit industry proposals for six-month conceptual studies on an aircraft to provide Tactical Air Command with an autonomous capability to detect and destroy hard mobile targets, but the program was not funded.

The Carter administration commissioned only a few paper studies on the problem. It was not until June of 1981 that the Air Force Aeronautical Systems Division issued a Request for Information (RFI) on an aircraft dubbed the Advanced Tactical Fighter (ATF). An RFI broadly defines a mission, a threat, and a desired service-entry date, without any

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particular specifications, and lets the contractors take it from there using their own funds. RFI's have been unofficially described by one Air Force officer as ways "of getting industry to pay for our studies."\textsuperscript{12} The service was simply looking for realistic appraisals of what was technically feasible and cost-effective for a future system to perform the stated mission.\textsuperscript{13} The deadline for RFI responses was set at August 1982. By that date, many new technologies applicable to fighter design had begun to reach maturity in areas that included composite materials and lightweight alloys, advanced flight control system and avionics options, propulsion system upgrades, and low observables (stealth) technology. Concurrently, it was projected that by the time the ATF was integrated into the operational service inventory, all front-line Air Force and Navy fighters, including the F-15, F-16, F-14, and F/A-18, would be nearing the end of their respective service lives.\textsuperscript{14}

Two mission element need statements (MENS) accompanied the RFI, one for an air superiority fighter, the other for an

\textsuperscript{12} Sweetman, 1991, p. 12.


attack aircraft. As of mid-1981, the service planned to carry both sets of requirements in parallel in order to preserve its options for both missions.\textsuperscript{15} Indeed, at that time, some Air Force officers believed that, by the time the aircraft was ready to move into full-scale development, technological advances would have enabled the development of a true multi-role fighter without the weight penalties traditionally associated with such an aircraft. Designs under consideration for such a multi-role aircraft included modules to configure the aircraft for specific missions, and the use of a single airframe but changeable wings for air-to-air vs. air-to-ground operations.

Industry answered the ATF RFI with a wide range of concepts, from a Northrop's 25,000 pound fighter smaller than the F-16, to Lockheed's Mach 2, 120,000 pound "battle cruiser." Some of the designs had delta wings; McDonnell Douglas' proposal had an ultra-thin section straight wing; Grumman proposed a swing wing.\textsuperscript{16} Boeing's proposal stressed ground attack. One McDonnell Douglas paper, however, summed up the three critical common attributes of all the responses: short take-off and landing (STOL), stealth, and supersonic


cruise (supercruise).\textsuperscript{17}

The STOL requirement stemmed from concerns about Warsaw Pact attacks on European airfields. Air Force specialists estimated that if the ATF could land in less than 2,000 feet, and if air crews could fix 2-3 craters per hour, an all-out attack on airfields would reduce sortie rates by only 20\%.\textsuperscript{18} Stealth had been widely discussed for several years, but the basic technologies and the existence of a few small prototype stealth aircraft (early versions of the Lockheed and Northrop stealth fighter and bomber) were at that time so highly classified that many of the people involved in the ATF studies were not aware of them. While most of the people involved in the early stages of the ATF program therefore thought that stealth had potential value, there was some doubt about whether it could be incorporated into a high-performance aircraft. The last requirement, sustained supercruise (Mach 1.4-1.5) at about 70,000 feet, was inserted in order to remove smaller surface-to-air missiles from the threat environment altogether, to dramatically shrink the lethal envelopes of the larger SAM systems, and to escape Soviet fighters' new lookdown/shotdown capability. It was estimated that the combination of high cruise altitude and speed could reduce the


\textsuperscript{18} Sweetman, 1987, p. 73.
fighter's SAM exposure by a factor of three, with a possibility of even greater reduction of kill probability because the SAM's are least maneuverable and most likely to fail to track their targets at the extreme upper edges of their operational envelopes. The SR-71 had successfully exploited this "high-fast sanctuary" for years.

In October of 1982, representatives of most of the U.S. fighter manufacturers, many of their equipment suppliers, and Air Force planners and requirements specialists met in Anaheim, California for an ATF brainstorming session. The outlines of the aircraft began to emerge at this meeting: a supercruise aircraft, with reduced observables and a combat radius of 700-920 miles, able to take off and land on a 2,000-foot runway. The Air Force further concluded from the RFI responses that range and supersonic persistence set the lower boundary on the size and weight of the aircraft, and price set the top limit. It appeared as though an interdiction/strike aircraft would weigh about 80,000 pounds, and a counter-air fighter about 60,000 pounds.

At the same time that the Air Force was reaching this conclusion regarding the relative sizes of a strike aircraft as opposed to a pure fighter, however, both General Dynamics

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19 Sweatman, 1987, p. 75.


and McDonnell Douglas were actively arguing that the F-15 and F-16 could easily be modified for the strike mission. Indeed, each had built unsolicited demonstrator prototypes to prove it, and McDonnell Douglas was offering a firm fixed-price contract to build the aircraft.\textsuperscript{22} The Air Force modified its fighter procurement plans accordingly; a strike version of one of the two older aircraft would suffice to perform that mission (McDonnell Douglas eventually won that contest with the F-15E), and F-111's would be modernized and kept in service until well past the year 2000.\textsuperscript{23} Other factors also contributed to the definition of the ATF as a counter-air fighter: the perception that the Soviet Union was moving toward US-style air superiority fighters and fighter tactics; and the ever-hovering specter of the F-111 program, in which a dual-mission procurement program ended up with an over-budget and overweight single-mission aircraft.\textsuperscript{24}

The ATF would therefore be a pure counterair fighter, a direct replacement for the F-15. The Air Force decided at


\textsuperscript{24} Sweetman, 1987, p. 92. Many in the Air Force had been questioning the wisdom of attempting another multi-role aircraft all along. See Jay C. Lowndes, "Defense Studies Specialized Aircraft," Aviation Week and Space Technology, 5 October 1981, pp. 81-84.
that time that some 750 aircraft would eventually be procured, at a rate of 72 per year. Even at this early stage, questions were raised about how realistic Air Force budgetary projections were for the aircraft. The service's initial cost estimates were based on this 72/year production rate, and yet even the less expensive F-15 had been procured at a maximum rate of 42 copies per year. It was probably unreasonable for the Air Force to have expected that it would ever receive annual funding for this high purchase rate; at the lower rate, unit costs would be increased considerably.

The decision to optimize the ATF for the air-to-air role meant that the Air Force now had a reasonable sense of the aircraft's eventual size and speed, and consequently knew roughly what kind of propulsion system it would require. The Request for Proposals for the ATF engine, then known as the Joint Advanced Fighter Engine (JAFE), was issued in 1983; because of the development problems encountered with the F-15's F100 engine, the Air Force wanted to get an early start on the propulsion technology this time in order to preempt possible problems. General Electric and Pratt & Whitney were awarded contracts in September 1983 to build and test prototypes of their competing engine designs, each worth $203

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over 50 months. The winner would also propel the Navy's advanced fighter aircraft for the 1990's. 26 The engine program was quite loosely structured to encourage the competitors to take risks with new technologies.

An ATF Systems Program Office (SPO) was formed in 1983 under the aegis of the Aeronautical Systems Division (ASD) at Wright Patterson Air Force Base, headed by Col. Albert C. Piccirillo. Its first task was to produce an aircraft specification which met all the users' essential requirements, and as many of their "it would be nice" as possible, but to avoid requirements of marginal value and disproportionately high cost. 27 According to Piccirillo, "Early in this stage, we found four or five drivers (specific requirements which added substantially to the fighter's weight), and making just one of them cost us 10,000 pounds." 28 For this reason, the SPO was careful about each fraction of a percentage of performance requirement tacked on to the system specifications.

Even at this stage, the Air Force's Director of Operational Requirements stated that it was impossible at that time to predict what the ATF would be able to do that existing


27 According to one source, this process was held up for three months at one point, at Lockheed and Northrop's request, so that the ATF specification would take the stealth technologies being developed by these companies into full consideration. See "ATF Is Delayed To Add Stealth Technologies," Defense Week, 27 June 1983, p. 4.

fighters could not; "part of the reason for getting started is to be able to tell you the answer to just that question." He seemed, however, to stress simply that the primary impetus for the new fighter was the availability of new technologies. "All of those things [light-weight composite structures, propulsion technology, and avionics] would be a shame if we didn’t put them into our next-generation fighter." Since the United States cannot afford to match the Soviets fighter for fighter in sheer numerical terms, he continued, it must exploit its traditional forte of technological superiority.29

After four complete drafts, the Air Force reached a near-final requirement at the end of 1984. It called for an aircraft with an operational radius of about 800 miles (enough to allow it to cover all of Central Europe from bases in England and also to function effectively in other regions, mainly the Middle East), Mach 1.4-1.5 speed over that part of the mission that would cross hostile territory (up to 300 miles in and out), supersonic maneuver capability (6 G’s up to Mach 1.8), the ability to operate from less than 2,000 feet of runway, and a maximum takeoff gross weight of about 50,000 pounds.30

In addition, for the first time in any major program, the


Air Force set and published economic requirements in addition to operational targets. The flyaway cost, defined as the price of one fully equipped aircraft, averaged across the entire production run, was not to exceed $40 million in 1985 dollars. The total life-cycle cost, which includes the cost of the aircraft, the spares and fuel it consumes during its service life, and the cost of all the man-hours required to fly and maintain it, was not to exceed that of the F-15. Logically, since the ATF flyaway cost as higher than the F-15's, the other components of ATF life-cycle cost would have to be reduced. The aircraft would have to be more reliable, more durable, and more maintainable. Because propulsion systems and avionics consume the most spare parts and maintenance time, these systems received the bulk of reliability and maintainability attention.

A formal RFP for the Advanced Tactical Fighter was issued in September 1985, with the final submission date to be January of 1986. The only substantial alteration of the SPO's requirements was a cut in the target price to $35

31 This was higher than that of an F-15, but by a much lower margin than the F-15 exceeded its immediate predecessor, the F-4. See Sweetman, 1991, p. 14.


33 It is important to note that this RFP had initially been scheduled for release in December of 1984, then postponed until March 1985, and finally issued some months later. The delay was caused by tight budgets and resulting arguments that it would be more prudent to upgrade the F-15 and F-16 than to procure a wholly new aircraft. See "Advanced Fighter Proposal Bids Delayed Again," Aviation Week and Space Technology, 1 April 1985, p. 17.
million a copy based on a total buy of 750 aircraft, although it was assumed that upward cost pressures during design and development would push the price back toward $40 million again.\textsuperscript{34} The tight January deadline was later extended to April. Seven companies responded. The Air Force was able to demand fixed-price contracts for the development phase for the simple reason that the contractors needed the business. As one high-ranking Air Force officer admitted, "We looked at the marketplace, we saw what the marketplace was willing to do, and we took advantage of it. Any prudent businessman would do the same bloody thing."\textsuperscript{35}

Protecting Organizational Missions and Needs: Reducing Risks to Protect the Program

At that time, the Air Force expected to issue Dem/Val contracts to three or four airframe companies, without the construction of flying prototypes. Initial studies leading to actual flightworthy aircraft would be accommodated at relatively modest cost by building full- and reduced-scale models for wind-tunnel testing, radar cross section (RCS) computations, avionics development, and miscellaneous subsystems testing. State-of-the-art capability in such


sciences as computational fluid dynamics (CFD, used for extremely accurate wind tunnel assessments of analog hardware), RCS, and sub-system test rigs interfaced with advanced computing capabilities greatly reduced what would otherwise have been an extremely expensive full-scale prototype flight test program.  

General Dynamics and McDonnell Douglas, as the manufacturers of the F-15 and F-16, seemed at the time to have the inside track. Grumman, although it had built the F-14, was known as a "Navy house" and had dealt infrequently with the Air Force community. Rockwell was so heavily preoccupied with its B-1 bomber work that its ability to respond to the ATF RFP was limited. The other three seemed to be completely out of place: Boeing had never built a jet fighter or manned supersonic aircraft; Lockheed and Northrop had not built an air-to-air fighter for the Air Force since the 1950's.  

Lockheed and Northrop, however, each had an unexpected advantage -- stealth. While the ATF requirements were being worked out, stealth technology had matured in the Lockheed F-117 and Northrop B-2 programs. By 1985, both companies felt that they could design a low-observable fighter that would embody the same aerodynamic qualities as a non-stealth aircraft, and for similar procurement and operation costs. The Air Force decided to let them try. In January 1986, the


Air Force announced that the RFP response deadline would be extended to late April, in order to give the other competitors a chance to incorporate stealth techniques into their proposals as well.

The Air Force decided early in the ATF planning stages that the technical risks involved in the program were too great to take it straight from a design competition on paper into a single-company full-scale development program. This decision was also motivated by fears of escalating costs if unexpected technical difficulties surfaced. The major question was therefore whether to fly prototypes of two or more ATF designs. The Air Force was initially opposed to a prototyping strategy because the up-front expense would have limited the program to two competitors; if more than two promising designs emerged from the RFP stage, good ideas might have to be eliminated from the program. No one denied that airframe prototype competition was still valuable, but the combination of cost and new on-the-ground techniques for airframe evaluation led to an initial decision against it. Another factor in the decision was that many of the most


40 Wind tunnel testing had been improved and augmented with laser imaging techniques, computational fluid dynamics, and indoor radar cross-section ranges. For technical details, see Sweetman, 1991, p. 20.
important technical challenges in the ATF were related not to the airframe, but to the avionics, which would not be included in a conventional prototype aircraft. Finally, the Air Force also shunned the prototyping concept because it had already validated the stealth concept through the secret Lockheed and Northrop programs. The Air Force accordingly decided to compete the aircraft only through the Demonstration/Validation phase (Dem/Val), which included wind tunnel tests, subsystem tests, mockups, man-in-the-loop simulations, and supportability demonstrations, but not a competition between flying prototypes. This procurement philosophy was incorporated into the October 1985 RFP.41

The primary objectives of the Dem/Val phase included refining ATF system requirements; evaluating high-risk, high-payoff technologies for achievability, affordability, producibility, and supportability; and reducing technical, supportability, producibility, cost, and schedule risks for full-scale development. The seven involved contractors spent an average of $2 million each to prepare for the competition.42

A Dual-Service ATF: Round One


Around this time, Congress floated the idea of combining the Air Force's ATF program with the Navy's Advanced Tactical Aircraft (ATA), a long-range, heavy-payload aircraft intended for the medium-attack mission, in order to save money. The Navy had examined the possibilities for such a multipurpose aircraft in the early 1980's and had deemed such a program too expensive; similarly, the Air Force had considered adding the strike mission to the ATF and had concluded that the result would be unwieldy and unaffordable. In order to forestall disastrous Congressional interference, the services agreed to combine their programs in a more palatable manner. The Air Force agreed to consider the ATA as its F-111 follow-on, and the Navy would do likewise for the ATF/F-14. The agreement was deliberately vague on several counts, including timing (neither the F-111 nor the F-14 was due for retirement until the late 1990's) and the extent of the modifications required to either aircraft. Both services were deferring serious consideration of commonality in order to protect the single-service integrity of their core programs.

Tight budgets also threatened the pace and scope of the program around the end of 1985 and beginning of 1986. Piccirillo aired concerns in November of 1985 that Congressional budget cuts might force him to eliminate some emerging technologies from the aircraft and further stretch

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its schedule." According to Congressional staffers, however, Capitol Hill's questioning of the program was meant to signal concern that the Air Force did not have a firm grip on the ATF's schedule and costs. According to a November 1985 Senate report, "The current program does not provide sufficient time to absorb all of the [envisioned] technology, and the program entails unacceptable risks." This exchange would prove to be merely a warning shot in the fierce political battles that would eventually surround the ATF as it began to demand a larger share of scarcer defense funds. The Air Force responded in these opening rounds by claiming that the use of advanced technologies, particularly electronics and material sciences, would actually reduce overall costs.

Shifting Procurement Strategies to Preserve Up-Front Funding

In May of 1986, Secretary of the Air Force Edward C. Aldridge announced a change of plan; the Air Force would order two flying prototypes of ATF designs. Four factors dictated the switch. One was the Packard Commission's strong recommendations for flying before buying; the Air Force wanted

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45 Denny, Defense Week, 18 November 1985, p. 5.


to garner political capital by demonstrating that it was prepared to accept outside advice on such a major program. Another was that Lockheed's and Northrop's proposals clearly stood out above the rest; one Air Force official commented at the time, "We had two excellent proposals, three good proposals, and two who just didn't quite get the idea." This fact eliminated prior fears that good ideas would be eliminated if solid proposals were weeded out from the competition prematurely; it also prompted Air Force hopes that an early decision to select only two winners would encourage the contractors to form teams, so that elements of the three "good" proposals would not be lost.

The third factor was stealth. The fact that prototypes would be flown before funding was committed to full-scale development meant that engineers could experiment with the combination of supercruise, stealth, and maneuverability more freely, developing unconventional configurations which might have been considered too risky if they could not be tested at full scale. The final, and perhaps most important, reason for the changed acquisition strategy was that it justified a stretchout of the Dem/Val phase from 1989 to 1991. Program Manager Piccirillo explained, "We can [in this manner] greatly reduce the risk of the program. The up-front cost for the ATF

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development will be greater, but the overall program cost we expect will be lower."

The amended procurement strategy also permitted the first flight of prototype aircraft almost two years earlier than had been originally planned. Several defense industrialists at the time questioned the wisdom of the change on those grounds. It seemed to them that, if the prototype were constructed earlier, the ATF would embody far less advanced technology than would otherwise have been the case. "Contractors will spend the next 30 months in the assembly plant putting together a prototype instead of in a laboratory testing advanced components." Indeed, the service froze the ATF design in late 1987, much earlier than would have been the case under the old procurement strategy, in order to allow "ample time" for prototype construction. If, however, program officials correctly perceived that budgetary restrictions would get tighter and tighter in the months and years to come, the strategy was a shrewd one. Congress is much less likely to cancel a program in which substantial funds have already been invested, and particularly one in


which impressive flying prototypes have captured the public eye as early as possible.

Risk-Reduction Strategies: Teaming Through Dem/Val

In the summer of 1986, General Dynamics, Lockheed, and Boeing announced that they would team to develop the ATF if any of their programs were selected;\textsuperscript{54} a few weeks later, Northrop and McDonnell Douglas announced a similar arrangement.\textsuperscript{55} This strategy benefited all parties involved. Although the Air Force deliberately avoided actively encouraging a teaming strategy, it delivered the service the benefit of bringing the three middle-ranking contenders, General Dynamics, McDonnell Douglas, and Boeing, into the program.\textsuperscript{56} For the companies, it offered the burden of sharing in the risks and costs on the one hand, but the opportunity to share in the profits on the other. Cost-sharing was

\textsuperscript{54} Lockheed apparently made the first move; Sherman Mullin, manager of the Lockheed Dem/Val program, said, "We made a cold assessment and figured we could probably win the first phase on our own, but that we wouldn't win the final competition alone." See Bill Sweetman, "The Stealth Master," Interavia Aerospace Review, February 1992, p. 30.

\textsuperscript{55} Rowan Scarborough, "Second ATF Team Will Form," Defense Week, 7 July 1986, p. 3. The formation of these teams in no way limited Air Force source selection options. The service was still free to select two contractors from the same team as the winners, if it considered that to be the most appropriate choice. The contractors said that, in that event, they would simply scrap the teaming arrangements. Mark Daly, "US Air Force Set To Decide On ATF Prototypes," Janes' Defence Weekly, 25 October 1986, p. 928.

particularly important. With defense budgets declining, defense production was becoming a buyer's market, and the Air Force could afford to set its own terms for the Dem/Val contract; the competitors knew they would be lucky if Air Force funds would cover half of the cost of the work.\(^{57}\) The payoff, of course, would come to the winner of the full-scale development and production contract. On the other hand, the process of teaming was sometimes painful for the participants; each contractor had its own ideas about how to design the aircraft, and over a year's worth of discussions, arguments, and negotiations (referred to as "melding" by one participant) went into the agreements on which portion of the design each would be responsible for, and whose ideas and designs would be used.\(^{58}\)

In October 1986, Lockheed and Northrop were awarded parallel $691 million contracts as the winners of the Dem/Val phase of the ATF program. Their prototype aircraft, dubbed the YF-22 and YF-23 respectively, were scheduled for first flight in late 1989. The Dem/Val phase, scheduled at that time to last for three years (it eventually stretched into four), was longer than normal for this type of program because

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\(^{57}\) The seven firms involved in the Dem/Val competition had spent tens of millions of dollars of their own money, absorbing the risk primarily because they knew that this would be the only large fighter contract for at least the next decade. See Rowan Scarborough, "Firms Plow Millions Into ATF," *Defense Week*, 28 April 1986, pp. 3, 15; and Sweetman, 1991, pp. 21-22.

of the care being taken to verify costs and performance.\textsuperscript{59} Colonel James A. Fain was placed in charge of the program.\textsuperscript{60}

Prior to this decision, a similar propulsion system competition had been initiated, pitting Pratt & Whitney against General Electric. The engine RFP, then referred to as the Advanced Fighter Engine (AFE) and later as the Joint Advanced Fighter Engine (JAFE) was released to the manufacturers during May of 1983. The following September, both were awarded $550 million contracts to build and test static prototypes.\textsuperscript{61}

The Demo/Val program was formally divided into three sections: the Avionics Ground Prototypes (AGP), which were used to demonstrate the achievability of the fully integrated avionics suites; the Systems Specification Development (SSD), which used effectiveness analysis, design trade studies, tests, simulation, technology evaluations, and other efforts to refine the weapon system characteristics and operational requirements; and the Prototype Air Vehicles (PAV), which were used to demonstrate the capabilities on which the F-22/F-23 EMD proposals would be based. The critical problem facing the competitors was to demonstrate that a stealthy aircraft could be fast and agile; aerodynamics, handling, and engine/airframe


\textsuperscript{60} Fain was promoted to Brigadier General in 1989. Sweetman, 1991, p. 22.

\textsuperscript{61} Abrams and Miller, 1992, p. 3.
integration were primary tasks at hand. The AGP was intended to design and test the entire suite of sensors, transmitters, processors, and displays, and although not required to do so, both teams elected to fly their avionics systems in an airborne laboratory. SSD is an umbrella term for the radar cross-section tests, development and testing of new airframe materials, exercises in flight simulation which pitted the ATF against hostile fighters and missile systems, and the demonstration of maintenance techniques. Under PAV, each team built two prototypes (known as PAV-1 and PAV-2), one powered by General Electric engines and the other by Pratt & Whitney engines.

Each team brought substantial, applicable experience into their partnerships. Lockheed had experience in F-117A program design and production; Boeing had strength in military avionics development and advanced materials development; and General Dynamics had experience as designer and builder of the F-16 and its advanced fly-by-wire flight control system. On the other team, Northrop offered expertise in low-observables technology, lightweight fighter design (considerable data remained from the F-5 and F-20 programs), and advanced materials technology; McDonnell Douglas had experience in fighter design and production.

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63 Abrams and Miller, 1992, p. 3.
Within-team division of labor was based on the dollar value of work performed. On the YF-22, General Dynamics built the mid-fuselage, the empennage, most subsystems, the armament system, the landing gear, and the vehicle management system integration (including flight controls); Boeing built the wing, the aft fuselage, and propulsion system integration; and Lockheed's Skunk Works division did the weapon system, air vehicle, and avionics system design integration, the forward fuselage (including the cockpit and air intakes), the wing leading edge flaps and tips, the vertical stabilizer leading edges and tips, the horizontal stabilator edges, and final assembly of the complete aircraft. On the YF-23, McDonnell Douglas assimilated production of the forward and center fuselage, the landing gear and wings, the fuel and armament systems, the offensive avionics, the controls, and the cockpit displays; team leader Northrop, already overloaded with B-2 work, assimilated most of the design and engineering effort, the total systems integration final assembly, construction of the aft fuselage and empennage, and defensive avionics and flight control system integration. The crew station and pilot/vehicle interface were a joint responsibility.

The PAV program was planned from the start to be rather compressed, in contrast to normal developmental flight test

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64 Abrams and Miller, 1992, p. 3.
programs which can involve thousands of hours of testing over a meticulously mapped and varied operating environment. It was aimed at only a handful of points on the edge of the flight envelope and was intended to cover only about 100 flying hours per design.\textsuperscript{67} The Air Force planned to issue an RFP for full-scale development to the competing teams as the Dem/Val phase drew to a close, this time for the complete ATF weapons system. The final decision would then be based on the data on the FSD proposal, not on the performance on the PAV's during Dem/Val. The PAV's therefore did not "fly-off" in the conventional sense; their function was merely to support the projections on which the FSD proposals were based.

Stiff requirements were set from the start for reliability and maintainability. The Air Force set specific targets for such parameters as MMH/FH (mean maintenance hours per flight hour), MTBMA (mean time between maintenance actions), and turnaround time between sorties.\textsuperscript{68} It also wanted to reduce the amount of specialized equipment that a fighter wing requires in order to sustain operations, primarily because of skilled manpower concerns stemming from the declining military-age population and increasing competition for labor from private industry. In order to support an F-15 wing, the Air Force uses personnel trained in

\begin{footnotes}
\item[67] Sweetman, 1991, pp. 23.
\end{footnotes}
25 different specialized tasks; for the ATF, it wanted to reduce that number to 8-10.69 Tactical Air Command requested that logistical and maintenance considerations result in an ATF fighter force with no more than 2% of the aircraft down to await parts at any given time.70

The Air Force continued to refine the ATF's operational requirements during the Demo/Val program. The most major change stemmed from a technical difficulty with the F-15 STOL demonstrator program. Pratt & Whitney engineers found that some of the cooling requirements associated with the vectoring and reversing engine nozzle were more difficult than originally anticipated; as the nozzle grew heavier, costlier, and more complex (if included, the final nozzle would have added 1,000-1,500 pounds to the empty weight of the aircraft), the Air Force realized that it had to relax the STOL requirement (from landing capability within 2,000 feet to 3,000 feet) and eliminate the thrust reverser altogether.71 The consensus was that the thrust reversers' attributes would have been offset by weight, maintenance, and cost considerations. Most importantly, full-scale testbed research had indicated considerable cooling difficulties and a

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propensity for the exhaust efflux to adversely affect directional stability when the reversers were used in flight.\textsuperscript{72} These anomalies would have necessitated design changes that would have affected the proposed ATF production schedule. Designed to operate throughout the ATF’s flight envelope, the reversers would not have been simply an extrapolation of extant reverser technology, but rather a major technology risk -- and thus an unknown quantity on an aircraft optimized for dependability and high performance. The fact that this problem was discovered and dealt with early in the program, rather than at a later stage when it would have been substantially more expensive to correct, is dramatic evidence of the value of the technology demonstration program.

Other trade-offs made during the prototype development phase included small changes in initial cruise altitude to target, and a reduction in the maximum number of g-forces the aircraft could sustain at certain weights. These changes were made largely in order to balance requirements with cost limitations, and prompted worries within the Air Force that budgetary constraints would severely tarnish the performance of the aircraft. Tactical Air Command head General Robert Russ, commented on the relaxing of the STOL requirement, summed up the service’s concerns: "I hope it does not mean we would start nibbling at the edges of the ATF. I would not want to

\textsuperscript{72} Abrams and Miller, 1992, p. 4.
start nickling and diming it because all that does is stretch
the program and increase costs."73 Some Air Force acquisition
officials, however, viewed the situation in a different light.
One explained,

When we first started the ATF program, it was sort of a
Christmas tree that everyone wanted to hang their
technological ornament on. Fiscal realities have cast a
pall on that technological enthusiasm in some regards.
But it is still going to be a technological marvel if we
incorporate true stealthy designs into a high-g, high
performance supersonic cruise airplane.74

The zeal with which the Lockheed and Northrop teams
plunged into ATF prototype development was a source of concern
among observers of the aerospace industry. At the time the
two firms were selected to compete, Program Manager Piccirillo
estimated that they would each spend from $300 to $500 million
of their own funds on the competition; as Paul Nisbet, an
analyst with Prudential-Bache Securities, commented, "It's the
future for all the companies involved here and there's not
much work if you lose."75 While in the short term these
demands on industry give the Pentagon some financial leeway,
in the long term they raise questions about whether the added

73 Morrocco, 1 February 1988, p. 18. For other Air Force
statements of similar concerns, see James W. Canan, "Backlash from

74 Quoted in John D. Morrocco, "Budget Pressures Forcing USAF
To Ease Requirements for ATF," Aviation Week and Space Technology,
28 August 1989, p. 25.

75 Rowan Scarborough, "Industry Teams Making History," Defense
Week, 10 November 1986, pp. 12-13. See also Richard W. Stevenson,
1989, p. 25.
financial pressure could eventually discourage companies from competing on new projects, potentially damaging United States national security, or will lead to cuts in other avenues of promising research. The effect on the defense industrial base of this potentially adversarial relationship between defense contractors and the Pentagon remains uncertain.

The contractors were also concerned at this stage in the program because the Air Force had said little about how it would eventually procure the fighter. If production were dual-sourced, as the Navy planned do to with the Advanced Tactical Aircraft, then the members of the winning team would be forced to compete for annual production buys, reducing their chances of recouping their early investments through the production contracts. These fears were assuaged in February 1988, when the ATF program office announced that it would fund only one production line operated by the winning contractor team, and would ensure continued competition in the program by relying on two sources for many subcontract components, where

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70 to 80 percent of the program cost would occur. The service guessed that an insufficient number of ATF's would be produced to justify the expense of capital investment in two assembly lines.

The original plan was for the prototype to fly in late 1989 for FSD proposals to be submitted in late summer 1990, and for source selection to take place at the end of 1990. In mid-1989, however, Lockheed announced that a previous decision to undertake a substantial change in YF-22 design in order to reduce its weight would delay the completion of the prototype. The Air Force agreed to extend the program by about six months; in order to spread out its work load and keep its team together until the source selection date, Northrop slowed the pace of its program. The Air Force also announced plans early in 1989 to delay the planned initial flight of the first full-scale development aircraft by one year, from 1992 to 1993, in order to take advantage of maturing technology, reduce program concurrency, and trim the defense budget.

Numerous unconfirmed reports around that time indicated that both competing teams were having difficulty keeping under

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the specified weight and cost limits.\textsuperscript{80} One industry source commented, "Everybody in the industry knows what the bogies are -- 50,000 pounds and $35 million [in 1981 dollars]. We will kill for 25 pounds. We have a sliding scale, with a list of all the characteristics the Air Force wants in the aircraft. Then we move the index up and down the scale to show what has to be given up to keep the weight at 50,000 pounds. We've been giving the customer a lot of choices, and a lot of decisions to make."\textsuperscript{81}

These concerns became so great in mid-1989 that the House Appropriations committee initially axed ATF funds from its FY 1990 appropriations bill. Apparently there was never any real intent to cancel the program; the move was merely intended as a warning to the Air Force to clarify Congressional concerns over the ATF's acquisition strategy, costs, and technical risks.\textsuperscript{82} The committee criticized the program for overly optimistic cost and production rate estimates, schedule slips, software problems, and plans to sign production contracts before full-scale development is finished. Although full development funding was restored, the incident, combined with


\textsuperscript{81} "Contractors Struggling to Meet Air Force Goals for New Fighter," \textit{Armed Forces Journal International}, February 1989, p. 29.

general concerns about the degree of financial risk being placed on industry in defense contracts, prompted the Northrop team to inform the Air Force in December 1989 that it was reducing its funding commitment to its ATF entry.83

A Dual-Service ATF: Round Two

The 1989 House report also accused the Defense Department of not being serious about making the ATF a joint Air Force-Navy plane. In fact, throughout the ATF development process, the initial Air Force/Navy deal to procure variants of each other's next-generation aircraft remained on shaky ground.84

Naval fighters are considerably different in design and mission than land-based fighters.85 High sink rate landings and catapult takeoffs on and off carriers mean that naval aircraft must withstand intense vertical and fore and aft stresses. The avionics, sensors, and weapons carriage, along with the mountings for these components, must be designed to withstand these shocks routinely. Attention to compactness in design is also an issue. Because space is at a premium on a carrier, for example, a Navy fighter must be designed for vertical engine changes, rather than simply removing the


84 For details on the relationship between the ATA and ATF programs, see Bill Sweetman, "Fear and Loathing in the US Fighter Game," Interavia Aerospace Review, July 1989, pp. 705-708.

85 See Art Hanley, "ATF: Can One Aircraft Serve Two Masters?" Aerospace America, March 1990, pp. 6-8.
engine from the rear as is done on land-based fighters. Naval fighter missions are also quite different from Air Force missions. The Air Force envisions fighter sweeps supported by AWACS, taking advantage of stealth and supercruise capability. Naval fighters' missions are much more specific, to intercept incoming bombers and missiles well away from their carriers, and therefore they must operate much more independently over enemy territory. Naval fighters must be more heavily armed to carry out more sustained combat. Supercruise is not as important to the Navy as is loiter time and range; stealth is not as important as is a powerful radar, since at sea navy planes require maximum detection range and long-range missile guidance. Even stealth technology itself poses a difficult engineering problem for the Navy. The F-117 and B-2 are carefully housed in protective hangars when not flying to protect the radar-absorbing material on their skins; Navy fighters are inevitably exposed to corrosive salt air.

Essentially, therefore, making the ATF carrier-capable would require result in a lower-performance, more expensive aircraft than the Air Force wants. From the Navy's point of view, the ATF had superfluous capability.

One major issue in ATA/ATF commonality remained the aircrafts' electronics. Because the ATA was about two years ahead of the ATF and the jointly-developed INEWS development schedule, the early ATA's would have to be built with significantly different electronic warfare equipment. Early
in 1991, consideration for a naval variant of the ATF was dropped, after the Pentagon decided that enough F-14's existed to satisfy the service's requirements through the year 2015. At that point, an F-14 replacement would have to be considered. Air Force Secretary Rice also stated that an ATF derivative was under consideration to replace the cancelled A-12.  

Source Selection: Risk Reduction over Performance

The YF-23 PAV-1 with Pratt & Whitney engines rolled out at Edwards Air Force Base on 22 June 1990, and made its inaugural flight about two months later. The YF-22 PAV-1 was unveiled at Palmdale on 29 August 1990 and flew for the first time one month later. Both PAV-2's took to the air in the following month, and flight testing was completed by the end of January 1991. The only guidelines set forth by the Air Force for the flight test program were that the prototype aircraft should be flown for the purpose of EMD (engineering and manufacturing development) risk reduction. The actual capabilities to be demonstrated during flight test were left to the discretion of the contractor team. In other words, the goal of the flight test program was to establish readiness for low-risk EMD and to generate flight test data required for

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87 Abrams and Miller, 1992, pp. 5-6.
the EMD proposal, not for the purpose of determining the full capabilities of the aircraft in the classic sense, nor to determine compliance with design requirements or specifications. In fact, in early 1990 the ATF SPO had requested that the teams provide pre-flight predictions of various performance characteristics against which they would be able to compare actual test results determined from flight testing. These preflight predictions were provided to the SPO at the "sealed envelope" performance during late June. These predictions were to serve as credibility criteria and as a "report card" to verify actual versus predicted performance -- again, as a risk measurement and reduction measure.88

The two competitors developed prototypes quite similar in some respects, and quite different in others. The most basic common feature is size, which is not surprising since they were designed to have the same range and payload, and to use the same engines.89 The Lockheed aircraft, however, was monolithic, with most of the aircraft's mass (engines and inlets, weapons bays, landing gear, and most of the fuel capacity) concentrated in a single box-like structure about 38

88 Abrams and Miller, 1992, p. 11.

feet long by 20 feet wide at its broadest point. The Northrop YF-23, longer and more slender than its competitor, had the appearance of being divided into three long bodies: a long, high forebody and two widely separated engine nacelles.  

Perhaps the most radical technological innovation to be incorporated into the ATF was its avionics. The development of very high-speed integrated circuits (VHSIC) was the cornerstone of Pave Pillar, the Air Force's new approach to aviation electronics in the early 1980's. The first generation of electronic systems installed on aircraft involved isolated systems performing various functions, leaving the integration of these tasks to the crew. Gradually, more of these devices were given the ability to communicate with one another; for example, radars were used to correct navigation systems. Systems were still, however, separately designed and developed, and each box containing the avionics equipment, the line replacement units (LRU), was different from all the others. Pave Pillar replaces all the specialized avionics computers and processing systems with VHSIC modules which, like personal computers, can be programmed to perform any of a variety of tasks. This agility

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means that one module can be reprogrammed in flight to replace another which has failed, or to provide extra processing power for a function which requires it for only part of a mission.\textsuperscript{92} These modules fit into slots built into the ATF, which provides them with power and liquid cooling.

The ATF does not therefore have a separate radar system, for example, like its predecessor fighter aircraft. Instead, the radar antenna functions as one a number of apertures, from which signals are processed by a bank of common signal processing avionics modules. These modules extract target returns and provide target data to the main mission processor, the display processor, and the rest of the avionics system. The pilot does not therefore see separate electronic warfare and radar targets, for example; the avionics modules integrate all this information and presents the pilot with one complete display. Communication, navigation, and identification functions behave similarly.\textsuperscript{93}

Another addition to the ATF avionics involves the Integrated Electronic Warning System (INEWS) program. INEWS is a long-term joint-service program which will be applied to

\textsuperscript{92} Sweetman, 1991, p. 67. Pave Pillar led to the formation of the Joint Integrated Avionics Working Group (JIAWG), an Air Force/Army/Navy group which has established common module specifications for all three services. JIAWG modules are just over six inches square and a little more than a half an inch thick, and now come in several different types to perform any of several generic tasks, including digital data processing, analog-to-digital signal processing, bulk memory, power supply, and others.

\textsuperscript{93} Sweetman, 1991, p. 69.
several next-generation Air Force and Navy aircraft. It replaces existing early warning equipment with a modular system that will combine an electronic warning system and a threat warning with the aircraft's other Pave Pillar Modules. Like Pave Pillar, INEWS promises to be more reliable and maintainable, less bulky and costly, and reduce the pilot's workload more than its predecessor EW systems.

Creating, testing, and validating the vast amount of software necessary to make this avionics concept work is an enormous task. In order to ensure that progress remained smooth, the Air Force asked its Scientific Advisory Board (SAB) in 1988 to review the entire ATF avionics program. Although it developed more than 50 major findings resulting in hundreds of changes to the Dem/Val program, its overall conclusion was that the risks involved in the avionics system were manageable. The final decision to commit to the new avionics system architecture was therefore made in late 1988. The Air Force clearly hopes that the early attention and expenditure devoted to the ATF electronics systems will preclude the much more costly exposure of defects later in the procurement process.

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95 The SAB is a quasi-independent body composed of engineers, academics, and other consultants.

96 Sweetman, 1991, p. 78.
On April 23, 1991, after a three-month review of the Dem/Val results and the associated EMD proposals, the Air Force selected the Lockheed team’s YF-22 aircraft and the Pratt & Whitney F119 turbofan engine designs as the winners of the ATF competition.\(^{97}\) An Air Force official familiar with the source selection procedure said that the winning contractors were rated higher in both their technical proposals and their plans for managing the development program, with the main factor in each of these ratings being the Air Force’s assessment of risk.\(^{98}\) Lockheed and Pratt were considered more likely than Northrop and General Electric to be able to accomplish what they proposed and to manage the development program successfully. Apparently the service also judged that the Lockheed-Pratt combination would be a few percentage points less expensive than any other airframe-engine combination. An Air Force official claimed that the risk assessments and cost estimates made the choice straightforward, observing that "it was very clean. There were not a lot of gut-wrenching calls to be made."\(^{99}\)

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In essence, therefore, the flight test program was not a flyoff, in which the performance of the competing aircraft was compared directly, but a data collection exercise through which the contractors tried to convince the Air Force that they could accomplish what they had proposed with the least technical and development risk. "Even if one prototype outdid the other in specific performance measures during flight tests, it did not necessarily benefit. The aircraft that did better still suffered if it failed to attain its predicted capabilities. The lesser performer gained if it exceeded predictions."\(^{100}\) Clearly, in this source selection, the Air Force wanted to minimize the risk that later technical, cost, or schedule problems would embarrass and perhaps jeopardize the ATF program.

The service may have had the luxury of this procurement approach because all four engine/airframe combinations met the Air Force's basic technical requirements, even though the Northrop aircraft was clearly st\(\text{st}\)althier and faster than the Lockheed design; according to ATF Program Manager Major General James A. Fain, "Neither maneuverability nor stealth were decisive."\(^{101}\) Lockheed's performance on the F-117 program was a point in its favor; in addition, most sources

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considered that Boeing, with its enormous and experience in manufacturing technology, large-scale program management, and systems integration, was also a major plus for the Lockheed team. Systems integration skill in particular is even more important in the ATF program than in previous aircraft programs because of the critical role played by the complex avionics system and its dependence on complex, integrated software.

The $11 billion contract to begin engineering and manufacturing development (EMD) of the ATF, now officially branded the F-22, was awarded on August 3, 1991. The cost-plus-award-fee contracts to both Lockheed (total $9.55 billion) and Pratt & Whitney (total $1.375 billion) allowed reimbursement of contractors' costs plus a base fee of 4% of the estimated cost of the contract. Also included was the potential for an additional 9% in performance-based fees. Overall reimbursable costs were capped at $12.7 billion for the EMD stage. 102 This stage consists of the manufacture and flight test of nine single-seat, two two-seat, and two fatigue and static test EMD aircraft. Pratt & Whitney are furnishing 33 F119-PW-100 engines for the flightworthy aircraft.

Fabrication of the first EMD F-22A aircraft, following freezing of the external design during October of 1991, was to begin during December of 1992 at Lockheed's Marietta facility.

Assembly of the last of the EMD aircraft was scheduled for late 1996 or early 1997, and was to be followed by four pre-production verification F-22As. The latter would then be used in operational Air Force tests and then introduced into the operational inventory. Full production of the F-22 was scheduled to begin during late 1997 or early 1998. At the peak of EMD efforts during mid-1994, the F-22 team was expected to number about 7,000 employees at the three companies, plus 650 suppliers in 32 states. A go-ahead by the Air Force for low rate initial production was scheduled for 1996.

**Threats to the F-22, Round Three: The Major Aircraft Review**

All did not go as planned. As it became more and more clear in the late 1980's that defense expenditures would undergo a possibly drastic decline in the years to come, in conjunction with a clearly diminishing military threat from the Soviet Union, Defense Secretary Dick Cheney decided to revisit some of the Air Force's recent aircraft procurement decisions (the ATF, B-2, C-17, and ATA). Another purpose of the Major Aircraft Review (MAR), which took place from January through April 1990, was to assess the trade-offs between moving ahead with systems that incorporated new technologies, such as stealth, or settling for upgrades of existing systems.
instead. The MAR recommended that the start of full-scale development of the ATF be held at mid-1991, but the number of aircraft to be built per year reduced from 72 to 48, with this rate reached in the year 2001. Stretching out the program in this manner would result in increased flyaway costs because of lost economies of scale and increased inflationary effects. The MAR also deferred production of the Navy’s ATA by two years.

Apparently several themes set the tone for the review. One was the reluctance of the Pentagon, particularly the Joint Chiefs of Staff, to change aircraft requirements because of the uncertain nature of the Soviet threat. If the threat scenario remains unchanged, then the need for a new air superiority fighter based on stealth technology does not change either. Some civilian officials in the Department of Defense, however, argued that the Soviet threat had diminished enough to allow for changes in the requirement for future American aircraft. Enough uncertainty remained, however, to validate the requirement. In the words of Defense Secretary Dick Cheney, "Soviet military capability will


continue to be robust, but we can afford to slow down the pace of developing and fielding the next generation of aircraft, in some cases can reduce the planned buy, and can extend existing systems longer than originally planned. We cannot cancel or halt modernization programs, but we can slow some programs and save some money.\textsuperscript{106} Cheney also argued that stretching out the advanced aircraft programs would provide more time to "iron bugs" out of the more advanced technologies before the decision to move on to production.

In addition to the overall technological threat posed by Soviet aircraft modernization programs, Cheney also cited the changing likely operational scenarios for war in Europe. He predicted that, in the event of large-scale conventional war, NATO would face fewer enemy aircraft, a reduced ground threat, and a less robust air defense threat over Eastern Europe itself. Finally, he held out the possibility of a longer service life for the F-15, which the ATF is intended to replace. Under old assumptions of a 6,000-hour operating cycle, the current F-15 fleet would begin to retire in the year 2000. More recent fatigue life testing, however, indicated that the F-15 airframe life could be extended to 8,000 hours, permitting a two-year delay in ATF procurement.

without adversely affecting approved force structure levels.\textsuperscript{107}

The review apparently failed to address issues of affordability. Pentagon officials claimed that they could not come to grips with this question because they lacked specific details of the military services' long-range budget plans. In particular, the services' budget proposals for the fiscal years 1992-1997 were not due until the end of April 1990, after the MAR was complete; without these numbers, Pentagon officials were unable to examine how the four programs fit within lower budget ceilings.\textsuperscript{108} One Defense Department official said that the review reflected the traditional tendency of the Pentagon, when faced with declining budgets, to try to get weapons systems into production before the crunch comes.\textsuperscript{109} Congressional critics further complained that the review examined the possibility of existing aircraft as alternatives to the ATF on the basis of data which had been supplied exclusively by the Air Force, despite the fact that the service clearly was biased in favor of going ahead with

\textsuperscript{107} DoD Major Aircraft Review briefing, 26 April 1990, p. 715; see also testimony by Maj. Gen. John E. Jaquish, Air Force Director of Tactical Programs, Office of the Assistant Secretary of the Air Force for Acquisition, in Department of Defense Appropriations, FY 1991, Part 4, Hearings before the Senate Appropriations Committee, 101st Congress, 2nd Session, 8 May 1990, p. 44.

\textsuperscript{108} Morrocco, 26 March 1990, pp. 18-19.

\textsuperscript{109} Morrocco, 26 March 1990, p. 19.
the new aircraft.\textsuperscript{110} In addition, the upgrades were studied only in light of the ATF requirements criteria, and not in the context of overall modernization of tactical forces.

The Air Force also managed to keep advanced F-16 follow-on designs such as the Falcon 21 from being evaluated as possible alternatives to the ATF during the MAR.\textsuperscript{111} The Air Force remained extremely reluctant even to discuss potential F-16 upgrades for fear that they might present competition to the ATF.\textsuperscript{112} One senior Pentagon official has noted that the Falcon 21 could provide real competition to the ATF, since the ATF stores all its weapons internally, limiting its payload. The semi-submerged weapons configuration carriage of the Falcon 21 would give it more flexibility in weapons carriage, while still providing a degree of low observability.\textsuperscript{113}

Decrying the Major Aircraft Review as a whole, one Congressional analyst commented, "How can you make a policy decision about the number of [aircraft] you want to buy when


\textsuperscript{112} John D. Morrocco, "Pentagon at Odds With USAF Plan To Delay F-16 Follow-on Decision," \textit{Aviation Week and Space Technology}, 11 June 1990, pp. 20-21.

\textsuperscript{113} David A. Brown, "General Dynamics Evaluates Concepts for F-16 Successor," \textit{Aviation Week and Space Technology}, 11 June 1990, pp. 21-22.
you’re admitting in other rooms that you’re very uncertain about the post-Cold War environment and thus uncertain about, among other things, what...requirements would be?" Another Pentagon analyst charged that the aircraft review "was just a big contrivance to justify the programs."

In addition, the Air Force and Navy cooperated in order to save each other’s programs. One MAR participant explained that "when the Air Force needed the Navy to back up its views -- and vice versa -- a helping hand was freely forthcoming."

**ATF Alternatives: 1991**

Primarily because of the its enormous price tag in the face of declining defense budgets and the evaporation of the Soviet threat, proposed alternatives to the ATF cropped up on the agenda. Some analysts suggested in the late 1980’s simply continuing with low-rate production of the F-15 and F-16, buying just enough to replace aircraft lost due to wear and tear and in accidents. The primary counterargument to this strategy held that the United States should not rely on mere technological parity with the MiG-29 and Su-27, and that even if the former Soviet Union remains benign, it still constitutes a potent threat through its arms sales.

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Another alternative, perhaps more realistic, was to upgrade current fighters with some ATF-type technology. An Air Force "Red Team," working together with General Dynamics and McDonnell Douglas, examined, in a four-month study beginning in the fall of 1988, how this might be done with the F-15 and/or F-16.116 Although some radar cross-section reduction techniques can be applied, it is clear that full-blown stealth capability cannot be retrofitted onto an existing aircraft. The Red Team therefore focused its attention on the possibility of incorporating the ATF engine and avionics into existing fighters. It is relatively easy to fit the F-15 and F-16 with the ATF engines, as they are fairly close in external size, weight, and airflow to the F100 and F110. Similarly, the new avionics modules are more compact and lighter than current systems, and so it is a relatively simple task to integrate them into existing aircraft with only minimal changes to the power supplies and cooling systems.

The resulting aircraft were the F-15XX (F-15) and the Falcon-21 (F-16), each of which had newer and larger wings.117 The new Falcon 21 wing was a tailless delta, while the F-15 derivative had a higher aspect ratio, thin-section wing, with


leading edge flaps, made of advanced composite materials. Although performance was improved over the base aircraft, it was still substantially below that of the ATF (particularly in the supersonic region), and with a weighty price tag. For the F-15XX, many of the life-cycle cost drivers, such as engine maintenance and fuel, would be the same as those on the ATF, resulting in no savings at all; non-recurring development costs are estimated at $3 billion (in 1990 dollars). The F-15XX proposal, according to Pentagon officials, "[made] the Air Force nervous."\textsuperscript{118} Indeed, many in the Department of Defense criticized the Air Force for being slow in providing alternatives to the ATF for review, supposedly in the interest of protecting the integrity of the ATF program. The Air Force was also quick to point out the ATF's vast improvement over any upgrade of the F-15, referring to the latter as the "Flying Tennis Court," "Flying Barn Door," and "Aluminum Overcast."\textsuperscript{119} According to some Pentagon officials, internal Air Force efforts to prevent an upgraded F-15 from competing with the ATF began in the mid-1980's, using such methods as delaying the ATF engines to prevent them from being tested in F-15 upgrades. These ATF proponents also wielded a classified 1989 Defense Intelligence Agency assessment of the Soviet aircraft threat which concluded that the Soviets remain a

\textsuperscript{118} Morrocco, 19 February 1990, p. 16.

formidable adversary because of their continued production of sophisticated hardware.

As opposed to the F-15XX, the Falcon 21 would have been significantly less expensive to operate than the ATF.120 Cost data from the Falcon 21 led to proposals for an "ATF Lite," a modern single-engine lightweight fighter which would be to the ATF as the F-16 is to the F-15. According to its advocates, "ATF Lite" would be less expensive to produce and operate than the ATF, could replace both the F-15 and F-16 (reducing overall unit costs with a large production run), and might be attractive on the export market. The aircraft was to be designed to match the ATF in every performance parameter except stealth and range. To save weight, it would probably have carried its missiles conformally instead of internally, eliminating the possibility of maximum RCS reduction. Its head-on RCS, however, could still have been kept quite low, and its performance could therefore have been quite adequate as long as another country did not establish the equivalent of the Warsaw Pact SAM belt. Its range, in the area of a 400-mile operational radius, presented a more intractable problem. While 400 miles is adequate for missions in Central Europe, a combat scenario there looked increasingly unlikely; operations in other important theaters, the Middle East in particular, would require a considerably greater combat radius. "ATF Lite," according to its detractors, in comparison with the ATF

therefore represents less than half the aircraft for more than half the money.\textsuperscript{121}

Only three months after the MAR, Congressional pressure prompted the Air Force to reconsider these F-15 and F-16 upgrades as alternatives to the ATF.\textsuperscript{122} The service's acquisition office directed the ATF Systems Program Office to conduct a mission analysis study of the F-15XX and the Falcon 21. Data from the study were then independently evaluated by the Air Force Center for Studies and Analysis at the Pentagon. The fact that the studies were conducted in-house by the Air Force, which was naturally reluctant to jeopardize the ATF program, was, in the words of one industry official, "sort of like having the fox watch the chicken coop." A Pentagon official concurred: "The Air Force is going to take a look at the F-15XX and F-16 alternatives and put them to rest."\textsuperscript{123} These studies were delivered to the Congress in June 1991, and as expected, they favored the ATF over upgraded existing aircraft; the Air Force's analysis once again, however, was based on the premise that the Soviet threat would continue to

\textsuperscript{121} Sweetman, 1991, p. 91.


The Multi-Role Fighter

Another F-16 replacement called the Multi-Role Fighter (MRF) burst onto the scene almost immediately after the EMD contract was awarded for the F-22. In early October 1991, the Air Force's Aeronautical Systems Division hosted a planning meeting with major airframe contractors; the service issued a request for information on the new aircraft, with responses due from industry by 15 January 1992 explaining how the program might take shape. The firms were asked to explore three options: a completely new fighter, a derivative of an existing fighter, or the "Block 60" upgrade of the F-16. Until the F-22 development contract was safely concluded, the Air Force was anxious to quell talk of the MRF; in the summer of 1991, it suddenly seemed anxious to push ahead with the new aircraft.

By April of 1992, senior Air Force officials had definitely chosen the MRF to replace the F-16 as the fighter force's numerical backbone and its primary close air support


aircraft, designating the project its number one priority following the F-22.  

Tactical Air Command's deputy chief of staff for requirements, Brig. Gen. George K. Muellner, observed that the F-16s would begin wearing out sometime between 2005 and 2015, and that since those aircraft constitute 63% of the fighter force, "I've got to replace them."  

The Air Force made these arguments despite high-level Pentagon support to make the Navy's AX attack aircraft a higher priority. TAC planners reasoned that they had considerable capability with the current force of F-117s, F-15Es, and F-111s to conduct battlefield and deep interdiction air strikes, which would also be the area of operations for the AX. But, according to Muellner, "if the F-16s go away, I don't have anything else to fill in" with aerial attacks on enemy forces that are engaged near the forward line of friendly troops.  

TAC planners believed their arguments had gained validity with the addition to conventional forces of SAC's long-range bombers. The B-52s, B-1Bs, and B-2s brought with them a strategic offensive capability that overlaps the interdiction role. This meant that even more forces in the new Air Combat Command are capable of conducting interdiction

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and deep strike missions. "That's why we see the MRF as being more important than [the AX]," Muellner said. "It becomes a higher priority than replacing these interdiction assets."

In May 1992, the Air Force was considering three options for the MRF: a "modest" F-16 upgrade, a "significant" F-16 upgrade, and an entirely new aircraft. The "preferred option" was not to be decided upon until the service was ready to proceed into demonstration/validation, according to Air Force officials. An operational requirements document and a cost and operational effectiveness analysis were also to be done by the time dem/val was initiated. Depending on which option was approved, the service would then make final decisions on whether to award competing contracts, and whether a "fly-off" of prototypes was required. Speculation grew that the budgetary requirement to keep MRF at $25-35 million per aircraft dictated that only an F-16 upgrade was possible. The Air Force emphasized the continued need for an MRF to modernize the fighter force after the year 2000, as the F-16 wears out. Changes in doctrine, force structure, and tactics/training would not be enough to forestall a fighter shortfall, an Air Force source said.

130 Aviation Week, 6 April 1992, pp. 20-21.


Threat Assessments and Budget Cuts in the Post-Cold War Era: Why an F-22?

Also in early 1992, members of the House and Senate Armed Services committees began to question the rationale for the F-22. The F-22 had emerged remarkably unscathed from internal Pentagon budget deliberations prior to release of the FY93 budget request, despite Congressional leaders' questions about whether a program that will cost nearly $17 billion in its EMD phase alone can be afforded.\textsuperscript{133} Sen. Carl Levin, chairing the SASC's conventional forces panel in early April 1992, wondered why the F-22 remained untouched at the same time that the broader Pentagon acquisition strategy was to cut programs designed to fight the former Soviets. Levin asked Air Force acquisition chief John Welch, "Is it not true that the F-22 was justified over the years as needed to stay abreast with the Advanced Soviet Fighter? Was that not the previous justification for the F-22?" Welch replied: "Not to the best of my knowledge, sir. The justification was based on the need for air superiority in the future...I don't recall that it was the primary justification. It was certainly included in there."\textsuperscript{134} Levin claimed to be puzzled by Welch’s response, claiming that since the mid-1980's Air Force and Pentagon


\textsuperscript{134} Tony Capaccio, "Air Force To Get Grilling On Need For New Fighter,"\textit{ Defense Week}, 27 April 1992, p. 16.
statements have justified the then-ATF on the basis of Soviet advances.

During SASC testimony on the Major Aircraft Review on April 26, 1990, then-Defense Secretary Dick Cheney made the following pitch for the aircraft: "The ATF is the Air Force's next-generation air superiority aircraft designed primarily to counter improvements in Soviet aircraft and surface-to-air threats...The Soviet fighter threat has reached essential technological parity. We must not allow them or anyone else to dominate in the future." As early as March 1985, Air Force officials claimed as much. "The Soviets are moving along with capabilities in terms of quality to meet our F-15/F-16 fighters. They are producing in large numbers, as you well know," Maj. Gen. Harold Williams, then-head of operational requirements, told the Senate panel on March 12, 1985.\(^{135}\) This theme has been repeated up until April 1991, although tempered somewhat to reflect the changing situation in the Soviet Union. Maj. Gen. Joe Ralston, April 1991, then-Air Force director of tactical programs: "The Soviets have built the MiG-31, the MiG-29, and the Su-27. They have the counter-air follow-on to the Su-27 coming in around 2000. We are also concerned with other Western nations that are certainly upgrading their fighter aircraft and they are very likely to sell those to potential hot spots around the world that we

\(^{135}\) Capaccio, 27 April 1992, p. 16.
would have to counter."

Regardless of the rationale for the F-22, Congressional leaders questioned whether the aircraft could be afforded. John Murtha, House Appropriations Defense Subcommittee Chairman, said in April 1992, "I don't think the money is going to be there long term, even for the F-22. I foresee a real problem as we're squeezed down, with a diminished threat, of being able to finally build these things." McPeak admitted that the F-22 "will be a fight every year" (annual outlays in the EMD phase already exceed $2 billion), but be believed the program was fundable throughout its life.

USAF officials will resist having more than 60 percent of their planned fighter force composed of multirole aircraft. They maintain that the remainder must be split evenly between optimized air-to-air and air-to-ground roles. Following Murtha's F-22 warning, Air Force leaders were quick to respond that although the disappearance of the Soviet Union had drastically diminished the former primary threat, the F-22 was still a central priority. The day after the Murtha hearings, Air Force Secretary Donald Rice said the F-22 "has never been based on a prediction that the Soviets were going to develop advanced planes at the turn of the century," but rather on the need to stay one generation ahead of all potential enemy aircraft. McPeak placed assessments of air

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136 Capaccio, 27 April 1992, p. 16.

137 Boatman, 2 May 1992, p. 784.
threats as a secondary concern, largely because he believed that the current F-15 force was sufficient to address this danger. Instead, McPeak focused on the fact that the F-22 would give the Air Force the vital ability to "bring the fight to the enemy." USAF offensive counter air doctrine calls for fighters to penetrate as deep behind enemy lines as possible to engage not only enemy fighters but support aircraft as well. "It is not that we want to beat some other fighter in one fight. It is that we want to be able to dominate the air space anywhere we go in the world to conduct military operations." Of prime importance in such an equation are the unique capabilities the F-22 would bring to air warfare in the early part of the 21st century. Unlike any other fighter, the F-22 is stealthy and can attain supersonic cruise, and "that's what gets you into enemy airspace." According to McPeak, low observables mean that opposing forces' air defense radars have less of an opportunity to detect and strike the aircraft. "If they do detect you, they detect you late. So it shrinks the warning envelope." He added that supercruise reduces the chances of engagement by air defense missiles: "You either fly over them or fly through the missile engagement zone so quickly that they can't react.

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138 Boatman, 2 May 1992, p. 784.
The point is, do we have to go into unfriendly airspace? If we never have to, then I can get by with an F-15 -- I can defend San Diego, California with an F-15s. We're saying we need to take this air force into an expeditionary mode. I don't care who we fight when we get there; we're going to be able to beat whoever it is.  

At issue as of early 1992 was not only whether both the Air Force and Navy could bankroll two new tactical aircraft apiece, but the sequence in which the services proposed to modernize their fleets. The planes, their respective program costs and fielding sequences were the F-22 ($75 billion), the F/A-18 E/F ($65 billion), the AX ($105 to 160 billion), and the MRF ($75 billion). Production of the first two was to start in FY 1996, the MRF by 2005, and the AX by 2010.  

House Armed Services Committee Chairman Les Aspin questioned why the AX, for example, a plane that was intended to replace the oldest planes in the Pentagon inventory, was the last of the foursome to be produced.

As a result of this questioning, in August 1992 the Air Force indefinitely put on hold plans to replace the F-16 with the MRF, saying that a new aircraft development and procurement program was unlikely before the end of the century.

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139 Boatman interview, 2 May 1992, p. 784.


1994, prompted airframe manufacturers to halt or greatly curtail design efforts. Air Force sources said they did not have a target startup date for the MRF program, and that work on drafting requirements documents and operational concepts had been suspended. Instead of the hundreds of millions of dollars worth of design studies and prototype contracts expected over the next six years, Air Force sources said that the decision meant that industry would receive only minor technology research contracts. All of the major U.S. airframe companies had begun preliminary design work on the MRF and associated advanced technologies, according to U.S. industry sources. Gen. Mike Loh, commander of the Air Combat Command, explained, "Our decision was budget driven. Right now, we don't see a new aircraft or an existing derivative of an existing aircraft that requires substantial research and development investment to be in the cards for our F-16 replacement anytime soon." Just a year earlier, service officials had argued that the Air Force could afford its F-22, a low-cost MRF, and its currently planned base force level of 26.5 tactical fighter wings. According to Loh, the service's first priority for fighter modernization was continued development and production of the F-22. Until the F-22 was largely paid for, Loh said, the service would be satisfied with continued purchases of small numbers of Block 50-model F-16s for the multi-role mission. Loh said his command was

preparing an F-16 roadmap that illustrated potential technology improvements to the workhorse, single-engine plane that comprised over 50 percent of the service's fighter fleet.\textsuperscript{143} Clearly the Air Force was rallying to protect the F-22 program, downplaying or ignoring any program that might challenge it for attention and funding.

In late September 1992, Air Force acquisition officials proposed trimming the initial F-22 production by two planes, leaving nine aircraft to be built under an eight-year contract with Lockheed. Two of these would still be the two-seat, F-22B trainer versions. The Air Force as of August 1992 planned to procure 648 F-22s through the year 2014.\textsuperscript{144} The plan to reduce the scope of the Lockheed contract was prompted by anticipated reductions in the service's overall budget through 1999. By deferring production of the two planes until 1999 or beyond, the service expected to save between $300 million and $500 million on the $9.5 billion EMD contract.

\textbf{Cost Overruns}

This Air Force move was probably in anticipation of Secretary Donald Rice's virtually simultaneous order to review the three companies developing and producing the F-22 to

\textsuperscript{143} Opall, 10-16 August 1992, p. 26.

control escalating overhead costs.\(^{145}\) The review highlighted growing concern among other Defense Department officials over the adequacy of industry efforts to slash costs as the number of aircraft being purchased rapidly declines. Rice said in a 15 September 1992 briefing to reporters at the Air Force Association's national convention that the service's Overhead Cost Analysis and Control Review would focus initially on Marietta, Ga.-based Lockheed Aeronautical Systems Co. and its major subcontractors, General Dynamics and Boeing. The review, prompted by the Defense Department's transition from firm fixed-price contracts to cost-plus awards, also covered other Air Force programs that stood to suffer from the indirect costs of higher overhead spread over a shrinking business base. Lockheed sources claimed that their problems were with their subcontractors, particularly Boeing. John Ralph, marketing manager for tactical systems for Seattle-based Boeing Defense & Space Group, said in September 1992 that his company had suffered more than most companies from increased overhead costs because of the number of high-priority strategic programs that were canceled or radically reduced by President Bush in 1992. "We were heavily impacted by the decision to cancel Midgetman, rail-mobile MX, Short-Range Attack Missile, and to cap the B-2 at 20."\(^{146}\)


\(^{146}\) Finnegar, et. al., 21-27 September 1992, p. 36.
It became clear in late 1992 that the F-22, formerly touted as the military's model development and acquisition program, was falling under funding shortfalls and excess costs that could add nearly $1 billion to the estimated $15.7 billion EMD phase. Projected 1993 costs, as of the end of 1992, were to exceed the Air Force's available budget by about $300 million, and Air Force sources said that number would rise through 1995.¹⁴⁷ Moreover, the Air Force had by the end of 1992 nearly depleted a $530 million contingency account intended to carry the program through unplanned spending (management reserve account, to cover unplanned design adjustments, material changes, or other contingencies) through the year 2000; the account, set aside at the beginning of the eight-year EMD effort, was about 85% used up as of September 1992. "What we have is a mismatch of numbers between what the Air Force committed to funding through our contract and what they requested from Congress," an industry official said in September 1992.¹⁴⁸

Along with the discrepancy between the dollars committed to industry and funding (a discrepancy of about $100 million) requested from Congress was another $100 million lost to Air Force overestimates of the impact inflation would have on the program. Maj. Gen. Richard Myers, Air Force director of


tactical programs, attributed much of these discrepancies to faulty contractor estimates of the industry's ability to meet program milestones.\textsuperscript{149} Much of the costs associated with the use of management reserve funds was connected with increases in contractor overhead and higher labor rates spread over a constantly contracting business base. Costs to complete the eight year EMD contract grew by $2.7 million from 1992 to 1993, according to the service's descriptive summary to Congress on its 1993 budget request. Donald Atwood, the deputy secretary of defense, ordered the cost increase in an August 1, 1991 memorandum in order to make greater allowances for technical risk, the descriptive summary stated.

The FY93 defense authorization bill let the F-22 proceed with full funding, but it required the Pentagon to submit a review of how the F-22 program could be produced at reduced rates instead of the 48-per-year planned starting in 1997.\textsuperscript{150} The bill also tied significant strings around $3.3 billion in funding for the three top tactical aircraft programs, the AX, F-22, and F/A-18 E/F. In a significant move meant to strengthen the hand of the civilian Pentagon leadership, the authorization language said the money "can be allocated among these programs in such manner as the Secretary of Defense determines." The bill language would allow the secretary to

\textsuperscript{149} Opall, 28 September - 4 October 1992, p. 36.

shift the money to the program he determined to be the most technically mature. "The changed threat, a declining budget, and the lessons of Desert Storm suggested the need for a different approach than what the Pentagon is proposing," the conferees said. "The conferees concluded the changing security environment requires a systematic review of roles and missions as well as a fundamental reconsideration of the Base Force. Without these studies to provide an analytic foundation, no definitive solution to tactical aircraft modernization is possible."

The conferees tied up 35% of the $3.3 billion pending submission of several reviews. One was a comprehensive assessment of long-term tactical aircraft acquisition policies, including a production rate analysis that looks at producing airplanes at a lower rate than now planned and in smaller quantities, with a reporting deadline of 15 May 1993 for this study (although this deadline was not written into law). The conferees also required that the Defense Science Board conduct a study on the use of a single aircraft type by the services when performing similar missions. It also directed the Joint Chiefs of Staff "to undertake a very comprehensive assessment of the roles and missions in tactical aviation."

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152 Capaccio, 5 October 1992, p. 11.
Facing these constraints, the Air Force in November 1992 presented to the Pentagon its preferred options for restructuring the F-22 program in light of growing costs and budgetary shortfalls, including building fewer development aircraft and delaying the start of production by a year until 2001.\textsuperscript{153} This plan was intended to address an estimated funding shortfall of as much as $1 billion over the years 1993-1994. The program uncertainties stemmed from a combination of economic and technical factors. Contractor cost growth was largely a result of increased labor rates and overhead costs due to fewer defense programs, with the increase estimated at $300-500 million for FY 1993. According to the F-22 team's cost-plus contract, the Air Force had to pay for any overhead increases. The problem was compounded by the fact that the program was underfunded to begin with, according to industry and congressional officials. They estimated a $300 million funding shortfall in the Air Force's F-22 budget for FY 1993 and 1994. This deficit was exacerbated by congressional reductions in Air Force R&D accounts, which added up to a $260 million cut in F-22 development funding. When combined, the total shortfall was nearly $1 billion.\textsuperscript{154}


\textsuperscript{154} Morrocco, 23 November 1992, p. 31.
Weight Problems

While the Air Force maintained technical factors were not a real issue, some Pentagon officials believed they were a larger factor in the restructuring effort than service officials would have liked to admit. "I suspect there are some technical non-deliverables," one Pentagon official said. The Air Force has been "fighting weight margins all along. They've been telling us the problem is in hand, but they haven't been very convincing." In fact, Lockheed instituted a stringent weight-control program for the aircraft, offering prizes such as a Kershaw "Big Jake" pocket knife, a Stanley cooler, Krups coffee maker, plastic water bottles, and a blue Helly Hanson windbreaker, for employees who come up with weight-saving ideas. When employees enter building L-12, Lockheed's temporary F-22 headquarters in Marietta, Ga., a banner reading "Your Ideas Take Flight. Don't Wait. Reduce Weight," greets them.

The General Accounting Office in a February 1991 report said a growth of 743 pounds already had increased costs $1.3 billion when calculated in inflation-adjusted, then-year dollars. Although the Air Force and Lockheed have kept both the empty and fueled weights classified, the aircraft's


takeoff weight, according to an October 8, 1992 Congressional Research Service report, is about 62,000 pounds. The Senate defense appropriations subcommittee in its report on the 1993 defense bill warned that "the F-22 is exceeding its unit costs and empty weight targets. The former condition could ensure the aircraft is unaffordable. The latter condition would cause mission performance targets to be missed."

F-22 program manager Mickey Blackwell insisted during a December 1992 interview that the "Weight Improvement Program" was not launched to stem a crisis situation. "Instead, we said we've got to declare a crisis to avoid a crisis." He said the aircraft's design is very near to the company's goal. A congressional source counseled caution over such optimistic assessments. "This was the team in the competition with the weight problems. They stressed super maneuverability. They wanted to knock the socks off pilots, but it meant a heavy, heavy tail section." The Lockheed plane features thrust vectoring exhaust nozzles located near the engines that turn the F-22 into an extremely agile aircraft but add weight. The Air Force had established a goal of 50,000 pounds during the contest to avoid gold-plating by the competitors. Lockheed's design was closer to 55,000 pounds. F-22 team managers have been forced to dig deep for cost savings because in several instances the program adopted weighty equipment that will save money in the long run. F-22 Technical Director Eric Abell says, "There's a dichotomy that says if I have the absolute
lightweight solution, I may have the most expensive solution. So there's a tradeoff of how much weight reduction you have to do, whether this is worth it versus performance." Abell cited the use of heavier than desired side-of-body joints mating the fuselage to the wing. "We opted not to take the lightest solution because it would have involved excessive scrap and rework. So it's a matter of picking the best integrated solution, which is not always the lightest."158

Weight problems continued to plague the F-22 throughout 1993, prompting the Air Force to establish a Weight Murder Board. Its primary goal was to eliminate 400 extra pounds that accumulated on the aircraft just since June 1993.159 The Board recommended more than 130 "diet plans" for the "porky" plane, and program officials hoped to start realizing some results by early 1994. Service sources said the reduction would take time, and would cause the program office to dip into an unspecified amount of excess funds set aside for program glitches.

Program Schedule

The Air Force, working with the F-22 contracting team, identified a series of options in November of 1992 to create

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a more realistic program schedule that would match funding levels, as well as reduce concurrency and risk. This "rephasing" effort, as Air Force officials portrayed the move, included a variety of options that would defer elements of the development program by varying degrees. It involved shifting some work to the latter stages of the EMD phase, with some of the more high-risk technologies to be introduced later as pre-planned product improvements. Taken together, industry and congressional officials said, the impact was likely to be a one-year to 18-month stretchout of development. Such a stretchout could result in large production contracts being signed before thorough testing is completed. A full-scale F-22 production decision would slip 18 months to July 2001; the first development flight set for October 1995 would slip 11 months; and the first flight equipped with full avionics would slip 11 months to December 1997.\textsuperscript{160} Although key test flights would be delayed under this scheme, the service still planned to make contract awards in December of 1995, 1996, and 1997, well before crucial tests of loads, flutter, propulsion performance, and airframe fatigue are completed and evaluated, according to an internal schedule. These plans introduced a higher degree of concurrency into the program, said one government source. "By December 1997, you'll have less than half the fatigue testing and propulsion performance completed

before committing to production bids," the source said.\textsuperscript{161}

Recent History: Clinton Administration Priorities

The first defense-related priority of the new Clinton administration in January 1993 was the receipt of a Joint Chiefs of Staff report on roles and missions in the post-Cold War world. A leaked December 1992 draft of that report indicated that the four tactical aircraft then under development -- the F-22, MRF, F/A-18E/F, and A-X attack bomber -- were unaffordable. The draft indicated that "the need for four new tactical aircraft procurement programs is definitely questionable. A further examination and comprehensive analysis of what aircraft are needed to be procured in the next ten years is essential."\textsuperscript{162} The final version of the report dropped this conclusion, apparently because of a sense that a planned phasing of the programs one after the other would relieve affordability concerns.\textsuperscript{163} Joint Chiefs Chairman Colin Powell continued, however, to state publicly that modifications were necessary of "all those aviation programs that are still in the queue" in order to make them

\textsuperscript{161} Capaccio, 30 November 1992, p. 8.


affordable, and other studies clearly indicated that, although the budget could accommodate research and development for all planned programs, production costs could create a huge spending bubble after the turn of the century. One defense official observed that, because each new aircraft design costs an average of 2-3 times the price of the model it replaces, either the defense budget must be increased or force structure decreased accordingly, or choices must be made among the new aircraft.

New Secretary of Defense Les Aspin responded to this budget pressure by proposing a series of new acquisition strategies in his first policy and programming guidance for the FY 1994 budget: upgrades to existing equipment, low-rate production of selected new systems, "prove out" of fully operational and producible prototypes, and purchases of "silver bullet" technologies that promised dramatic leaps in capability. Under the upgrade concept, new systems like the F-22 would have to compete with the systems they are designed to replace, in this case the F-15, to determine whether the new systems are cost-effective. Essentially, the new administration's defense budget reductions, coupled with the

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changed threat environment, were interpreted by many to mean that tactical aircraft modernization needs are not particularly urgent, that a generation of new weapons systems can be skipped, and that for the near future the Air Force could in many cases rely on upgraded versions of existing systems. Simultaneously, the defense industrial base would be preserved through low-rate production even of new systems, which could be modified on the assembly line as new technologies become available. The goal would be to stop the expensive ramp up for high production rates that almost never actually materialize, reducing overhead costs and stabilizing key production lines. 167

Formal decisions regarding future tactical aircraft procurement programs were made as a result of Secretary Aspin’s Bottom-Up Review, formally launched on 23 February 1993 to assess the costs of, and alternatives to, major weapons programs. Tables 5.1, 5.2, and 5.3 provide an indication of the many trial balloons that were floated during the course of the review and its results. Of particular

Table 5.1
F-22 Replacements/Follow-Ons

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<thead>
<tr>
<th>Multi-Role Fighter (MRF)</th>
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<tbody>
<tr>
<td><strong>Appeared on agenda:</strong> October 1991</td>
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<tr>
<td><strong>Purpose:</strong> F-16 follow-on; later evolved into dual-service replacement for F-16 and F/A-18</td>
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<tr>
<td><strong>Characteristics:</strong> Never well-defined; &quot;modest&quot; or &quot;significant&quot; upgrades to F-16, or entirely new aircraft</td>
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<tr>
<td><strong>Flyaway unit cost:</strong> $35-50 million</td>
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<tr>
<td><strong>Mission:</strong> Multi-role, including close air support</td>
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<tr>
<td><strong>Politics:</strong> Air Force hedged on MRF until F-22 well in pipeline</td>
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<tr>
<td><strong>Outcome:</strong> April 1993, pushed back on procurement schedule because of FY94 budgeting for Block 50 F-16 upgrades; cancelled altogether in September 1993 Bottom-Up Review</td>
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<th>Joint Attack Fighter (JAF)</th>
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<tr>
<td><strong>Appeared on agenda:</strong> April 1993</td>
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<tr>
<td><strong>Purpose:</strong> Mid-end replacement for MRF and Navy's A/F-X</td>
</tr>
<tr>
<td><strong>Characteristics:</strong> Reduced RCS; cheaper than the A/F-X, but more capable than the MRF</td>
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<tr>
<td><strong>Flyaway unit cost:</strong> $40-45 million</td>
</tr>
<tr>
<td><strong>Mission:</strong> Multi-role, perhaps reconfigurable to either attack or fighter mode</td>
</tr>
<tr>
<td><strong>Politics:</strong> Air Force and Navy jointly lobby for JAF as a means of protecting their core programs, F-22 and F/A-18E/F. Some Pentagon officials argued that JAF should also replace F-22. Effective politically for Secretary of Defense Aspin; lets him kill two programs that are still on the drawing board, while avoiding messy turf battle with services over the programs they most want. Some Navy attempts to define JAF essentially as a reborn A/F-X.</td>
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<tr>
<td><strong>Outcome:</strong> Fizzled out during Bottom-Up Review</td>
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<th>Joint Stealth Strike Aircraft (JSSA)</th>
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<tr>
<td><strong>Appeared on agenda:</strong> May 1993</td>
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<tr>
<td><strong>Purpose:</strong> High-end replacement for F-22 and A/F-X</td>
</tr>
<tr>
<td><strong>Characteristics:</strong> Large airframe, supersonic (but not capable of supersonic), variable geometry wings, thrust-vectoring engine nozzles</td>
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<tr>
<td><strong>Flyaway unit cost:</strong> Substantially more than JAF</td>
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<tr>
<td><strong>Mission:</strong> Multi-role, combining F-22's air superiority mission with Navy's requirement for stealthy, deep-strike aircraft</td>
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Politics: Steps on core service turf; Pentagon finds attractive because long-range, deep interdiction capabilities were proven to be most useful in the Gulf War.
Outcome: Unclear that ever seriously considered.

Joint Strike Technology Program (JSTP)

Appeared on agenda: June 1993
Purpose: Replace JAF
Characteristics: Modular construction, including technological breakthroughs in avionics, structures, composite skins
Cost: Unspecified
Mission: Technology program, meant to result in competing prototypes in early 2000s, operational strike aircraft by 2010-2012
Politics: Part of ongoing rumor mill during Bottom-Up Review
Outcome: Evolved into JAST

Fighter Technology Demonstration Program (FTDP)

Appeared on agenda: August 1993
Purpose: Replace JAF, A/F-X
Characteristics: Attempt to combine stealth technology with affordable airframes; varying characteristics depending on mission
Cost: $2 billion investment through 1999
Mission: Program to develop four separate prototypes, each of which would answer specific service requirements
Politics: Satisfies Aspin's desire to use prototype development to sustain industrial base. Satisfies service desires to maintain single-service, single-mission integrity of their aircraft. Part of ongoing rumor mill during Bottom-Up Review.
Outcome: Evolved into JAST

Joint Advanced Strike Technology Program (JAST)

Appeared on agenda: September 1993, result of Bottom-Up Review
Purpose: Technology demonstration effort, supercedes A/F-X and MRF. Requirements for future advanced aircraft will be based on technologies that flow out of JAST. In particular, attempt to determine whether technology exists to develop effective dual-service aircraft. Stress on common component development.
Characteristics: Technologies to be explored include sensors embedded in wing and fuselage; off-board processing; new propulsion technologies with military and commercial applications; advanced munitions; unitized composite structure; carrier-compatible stealth; low-observable weapons integration. Modular construction envisaged.
Cost: $1 billion investment through 2000, bulging to $2
billion/year between 2003 and 2006

Mission: No specific aircraft development until at least 2000. JAST technologies to be incorporated into new operational requirements by 1997.

Politics: Satisfies Aspin's concerns about maintaining engineering and industrial base. Industry executives concerned that emphasis on component technologies and neglect of airframe development will harm industrial base and eventual systems integration efforts. Substantial ongoing controversy over whether program will produce flying prototypes. Some officials worried that, if program not focused on specific requirement, will become "technological hobby shop."169 Navy resisting early prototypes in hopes that it can resurrect A/F-X through JAST. Air Force recently calculated that F-16 fleet service life may be shorter than expected, and therefore might want to turn JAST into F-16 follow-on. Dual-service program management, on a rotating basis, indicates that Pentagon is serious about jointness of program.

Outcome: Unclear that industry will put much funding into program until DoD defines it more clearly -- is it an actual aircraft or only a technology opportunity?

Table 5.2
Bottom-Up Review Options

Tactical aircraft options reportedly considered in Bottom-Up Review:

1. Cancel F-22 and A/F-X; keep F/A-18E/F, F-22+ or A/F-X+, and MRF

2. Cancel A/F-X, F/A-18E/F, and MRF; keep F-22 and JAF

3. Cancel A/F-X and MRF; keep F-22, F/A-18E/F, and JAF

4. Cancel F-22, A/F-X, and MRF; keep F/A-18E/F and JAF

5. Cancel F-22, F/A-18E/F, MRF, and A/F-X; keep F-22+ or A/F-X+, and JAF

The F-22+ would incorporate air-to-ground capability.
The A/F-X+ would have greater range than the A/F-X.

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Table 5.3  
Bottom-Up Review Results\textsuperscript{171}

The problem: Define theater air capability that meets military need at affordable cost.


Decisions:


* Proceed with F-22 (IOC: 2003), with ground attack capability (essentially the F-22+).


* Establish Joint Advanced Strike Technology program (critical components, technology demonstrators, joint munitions).

* Conventional capabilities for B-1, B-2.

* Standoff weapons for deep strike/hard targets.

interest is the manner in which the Air Force and Navy behaved during Congressional consideration of the short-lived Joint Attack Fighter (JAF) in mid-1993. In joint testimony to the House Armed Service Committee in May, Air Force Lt. Gen. Buster C. Glosson and Navy Vice Admiral William A. Owens jointly testified, in tandem, speaking with authority on each other's programs, that the A/F-X and MRF should be abandoned in favor of the JAF. Since the high-end JAF would require quite a few years of research and development, this jointly-preferred option would, of course, imply the retention of the services' core programs already in the pipeline, the F-22 and F/A-18E/F. In fact, Owens and Glosson explicitly addressed to the Committee the importance of building each other's key aircraft. This joint-service strategy evokes memories of the F-15 procurement, when the Air Force and Navy cooperated to convince the Pentagon and the Congress that each needed its own aircraft, and that attempts at commonality would sacrifice important operational characteristics.

The Air Force Saves Its Core Program: Ground Attack Capability for the F-22

The Bottom-Up Review called for the F-22 to be retained, but its characteristics were substantially altered and its

procurement rates affected as well. In particular, the addition of ground attack capability to the F-22 was one of the determining factors in it surviving the review.\textsuperscript{173}

This alteration in F-22 characteristics largely had to do with altered perceptions of the threat environment any future fighter might have to face. In particular, a Defense Intelligence Agency study released in February of 1993, tasked with examining the threat presented by enemy aircraft and air defense through 2005, observed that future American fighters face rapidly eroding air-to-air threats at a time when surface-to-air missiles continue to proliferate.\textsuperscript{174} The DIA document concluded that the Russian government had discontinued plans to build next-generation replacements for the MiG-29 and Su-27, the threat on which the F-22 was initially predicated, but that Russian and other surface-to-air missiles continue to proliferate. The report explicitly concluded that, since affordability concerns had become paramount, a threat-based investment in the Navy's air-to-ground A/F-X might be more prudent than the F-22. As one Pentagon official commented in an 18 February interview, "Since the F-22 is more oriented toward a more aggressive fighter threat, and that threat has become progressively


downgraded, it follows that the F-22 as a pure air superiority aircraft may provide less of a payoff than an A/F-X or an air-to-ground variant of the F-22." The Gulf War Air Power Survey, conducted by Eliot Cohen of Johns Hopkins University, reinforced this thinking with its finding that high-end strike aircraft capable of employing laser-guided bombs were highly effective in the Gulf theater.\textsuperscript{176}

The F-22 will therefore enter service with built-in ground attack capability, equipped to carry two joint direct-attack munitions (JDAMs) internally and two tri-service standoff-attack missiles (TSSAMs) under the wings. According to Lockheed/Boeing F-22 program general manager Gary Riley, "We are going to put air-to-ground capability in the airplane. The provisions will be in the first airplane, possibly the capability. We are at the front end of those discussions with the Air Force."\textsuperscript{177} Lockheed/Boeing concluded a June 1993 contract with the Air Force to add this capability to the F-22, supposedly increasing the weight by only 11 kilograms.

James A. "Mickey" Blackwell, Lockheed's F-22 program manager, has made it clear that the company was not originally under

\textsuperscript{175} Opall, 22-28 February, p. 22. See also John D. Morrocco, "US Aircraft Review Shifts Into High Gear," Aviation Week and Space Technology, 12 April 1993, pp. 28-29.

\textsuperscript{176} John D. Morrocco, "Reports Cast Doubts on Joint Attack Fighter," Aviation Week and Space Technology, 17 May 1993, pp. 63-64; Professor Cohen's remarks in a noon seminar at the Woodrow Wilson Center, Washington, D.C., 10 November 1993.

\textsuperscript{177} Quoted in Graham Warwick, "F-22s To Have Ground Attack Capability," Flight International, 2-8 June 1993, pp. 4-5.
contract to provide anything related to strike capability, but that the plane is "beautifully positioned" for that role, and that it will not take much in the way of modifications to make it happen.\textsuperscript{178} The aircraft’s stores-management system will be designed to that it can be used to handle air-to-ground weapons, and additional avionics, a forward-looking infrared systems and a laser designator will have to be added. Indeed, some analysts claim that, because of its combination of stealth, supersonic speed, and low probability of intercept radar, the F-22, using radar and JDAMS with terminal seekers, will be able to bomb through undercast as accurately as an F-117 in clear weather.\textsuperscript{179}

Why, given that a pure strike fighter, the Navy’s A/F-X, was already on the table, did the Bottom-Up Review cancel the A/F-X and alter the F-22 instead? Two factors explain the decision. First, the desired aircraft was to retain at least some air-to-air capability, and, as an April 1993 Defense Science Board Task Force on Aircraft Assessment indicates, "Modern aircraft designed for the air superiority role have been successfully adapted to the air-to-ground mission to include part of the deep strike mission. However, the reverse is not true: deep strike or attack optimized aircraft cannot


\textsuperscript{179} Bill Sweetman, "High Cost Cold Warrior?" Jane's Defence Weekly, 26 June 1993, pp. 19-21.
be modified to an air superiority/air warfare role." In other words, only an F-22 modification stood a chance of providing the appropriate operational capability from a technical standpoint.

There continue, however, to be dissenting voices on this point. Some industry sources explain that the F-22’s broken-edged design was geared for survival in the high radar frequency, air-to-air environment and not for low radar frequencies where a plane with long, straight leading edges can best hide from enemy threats. One observer commented, "It’s a basic law of physics. There’s no way that the F-22 will be able to fight its way through a heavily defended area the way the F-117 can." Those same observers are skeptical of plans to equip the F-22 with standoff weapons. One Congressional staff source claims, "Standoff weapons can be used on any platform. You don’t need to hang them on a high-priced stealth plane like the F-22...This appears to be a transparent attempt to rationalize the program by creating a new missions niche."

These dissenting voices render even more credible the second explanation for the F-22’s mission alteration, having to do with service politics. The Navy was more concerned with

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180 Morrocco, 12 April 1993, pp. 28-29.


182 Opall, 6-12 September 1993, p. 29.
protecting the already-established F/A-18E/F than with lobbying for the A/F-X; in other words, the Navy's stakes in saving the A/F-X, and therefore its willingness to redefine it into whatever form would be necessary to accomplish that end, were not as high as the Air Force's stakes in the F-22.

Recent F-22 Development History: Reducing Risk and Saving Money

Throughout 1993, several technical changes were considered at the margins of the F-22. One concerned the thrust vectoring system. The production F-22, as currently envisaged, will include thrust-vectoring nozzles in the engines, but the door has been left open for a less advanced, less costly system.\(^{183}\) The F-22 System Program Office at Wright-Patterson Air Force Base has been conducting a "trade study" on stealth, assessing sets of tradeoffs between stealth and other kinds of capabilities. Given the radical changes in the threat environment, and reduced budgets, designers are in particular asking whether previously-high levels of stealth are necessary in the rear of the aircraft. The chief design difficulty involved here is to match the thrust-vectoring nozzle to the back of the airframe, and make the seals work. If stealth requirements were eased only slightly, significant cost savings could be achieved. Eric Abell, the F-22's technical director and chief engineer, explains that the

\(^{183}\) See Oliveri, March 1993, p. 35.
difference between the two versions of the aircraft would not be "here I am invisible and here I'm as big as a barn," but merely "tuning on the margins."\(^{184}\)

F-22 engineers are also thinking ahead to eventual operation and maintenance of the aircraft from the very beginning of the program. As Lockheed designs the tooling, for example, it builds two sets of tools, one for itself and the other for the Air Force's logistics department. As a result, when the depot needs to replace a worn-out part, it can manufacture it in-house and avoid paying a contractor for the job.

The F-22 passed its Preliminary Design Review (PDR) in April 1993, marking the point in the Engineering Manufacturing and Development (EMD) phase in which the functional design of the weapon system is reviewed compared to its baseline requirements.\(^{185}\) The review covered such items as aircraft configuration, structures, materials, manufacturing processes, propulsion, and flight performance. Using data from recent wind tunnel, material, and structural tests, the PDR clears the way for the transition to detailed design of the aircraft and its subsystems.\(^{186}\) The final external F-22 design (before

\(^{184}\) Oliveri, March 1993, p. 35. Oliveri also outlines cost-saving technical changes in the avionics package and munitions carriage.


\(^{186}\) John D. Morrocco, "Lockheed Concentrates on F-22 Risk Reduction," Aviation Week and Space Technology, 6 September 1993, pp. 50-52. The Lockheed-Boeing team at PDR had conducted more than
air-to-ground capability was added) incorporated a number of changes from the prototype YF-22: 187

* 1.5-foot wing span increase, to 44 ft. 6 inches;
* decreased leading edge wing sweep, from 48 degrees to 42 degrees;
* clipped outer trailing edge;
* horizontal tail surfaces reconfigured to include a clipper outer trailing edge, but retaining roughly the same surface area as the YF-22;
* area of vertical tail surfaces reduced from 109 sq. ft. to 89 sq. ft.;
* overall airframe length shortened by slightly more than two feet;
* increased use of titanium and composite materials (30% and 26% respectively on the F-22, as opposed to 24% and 23% on the prototype), with a resulting cut in the use of aluminum;
* nose section blunter than on YF-22; and
* cockpit moved forward.

The airframe will be built in three separate locations, as was the case for the YF-22. Boeing will build the wings and aft fuselage in Seattle; Lockheed in Marietta, GA, will build the forward fuselage; and Lockheed in Fort Worth will build the mid-fuselage. Nine flying aircraft will be produced in the EMD phase, plus one static and one fatigue test aircraft. 188 The first three aircraft will be devoted to testing aerodynamic characteristics, flying qualities, loads, flutter, and weapons separation. Aircraft numbers four through nine are to be avionics testbeds. According to John

25,000 hours of wind tunnel testing.


W. Pieper, Lockheed's F-22 chief engineer and manager of the test and evaluation program, one unique feature of the program is the creation of a dedicated avionics systems integration laboratory at Edwards Air Force Base, California. "We will have a complete avionics and VMS (vehicle management system) replica of the airframe, including the cockpit with functional displays and radar."\(^{189}\) Basically a duplicate of the actual avionics integration laboratory in Seattle, the lab will allow Boeing and Lockheed to expedite the test process. "If we see something out of the ordinary in the test flight, we can go back into the lab and recreate the event to try to isolate the problem," rather than the usual process of "fly, fly, fix, fly."

The F-22 is one of the first aircraft production programs to move to "lean production" rather than mass production techniques.\(^{190}\) Parts of the F-22 will be made in flexible manufacturing cells which can change from making one part to making another in minutes, rather than hours. When a part design is released, the package includes the process that will make it -- according to lean production principles -- and the process that will repair it. The hope is that, as a result, the manufacturing learning curve -- the difference between the cost of the first and subsequent aircraft -- is "flat or relatively so," according to Mickey Blackwell, formerly F-22

\(^{189}\) Quoted in Morrocco, 6 September 1993, p. 52.

\(^{190}\) See Sweetman, 26 June 1993.
program manager and now president of Lockheed Aeronautical Systems Co.\textsuperscript{191} If everyone in an integrated production team agrees early and up front that a part is buildable, producible, and can meet targets, then costs are spread out rather than bunched at the beginning of production.

The F-22's next milestone will be the Critical Design Review, at which point 80\% of the design will be complete, scheduled for November 1994. The contractors submitted their final rephasing proposal in July 1993. It delayed many parts of EMD by more than a year, pushing completion of the first EMD aircraft to early 1996 and first flight in mid-1996.\textsuperscript{192} Initial operating capability is scheduled for 2003. Current plans are for eventual production of the F-22 at a rate of 24 per year. Such a low rate will allow the Air Force to incorporate new technological advances into the aircraft, and to meet different requirements with block changes. Under this stretched out procurement, new models will be produced every 5-10 years.\textsuperscript{193}

\textsuperscript{191} Quoted in Sweetman, 26 June 1993, p. 20.

\textsuperscript{192} Morrocco, 6 September 1993, p. 50.

Predictions Revisited: Conclusions About the F-22

The case of the F-22, the first U.S. fighter aircraft to span the Cold War and post-Cold War periods, is somewhat more complex in terms of its realizations of predictions from the various theories. Certainly early broad perceptions of need for a new aircraft were shaped by considerations of the technical, tactical, and operational challenges presented by the opponent's current and projected developments in fighter aircraft (I-A). The radars deployed on the most recent generation of Soviet fighters led American planners to reason that a stealthy, high-tech air-to-air fighter would be necessary to ensure air superiority in the skies over Central Europe.

It is also the case, however, that a whole series of new technologies was coming on line and was ripe for inclusion into a new, missionized aircraft, indicating that in the current time period, technology availability (II-E, II-F) may in itself serve as a sufficient driver for a weapons system development. This notion is certainly supported by the Air Force Director for Operational Requirement's 1983 statement that "all of those [technologies] would be a shame if we didn't put them into our next-generation fighter." It is difficult to argue that there has been a well-defined catalyst from the international threat environment to dictate the timing of the F-22's making its way into the development stream (I-C), as was the case with the F-15, F-16, and F-117.
The role of the external threat has continued to be problematic throughout the later development stages of the F-22. During both the 1990 Major Aircraft Review and the 1993 Bottom-Up Review, the Air Force, finding its prized F-22 threatened, staunchly defended the aircraft at least partially in terms of the continued Soviet threat it would have to counter. It is difficult to fathom, given the uncertainties and constant debates surrounding the health of the Soviet military apparatus, whether these arguments were rational responses to a carefully considered threat environment (I-A, I-C), or if they are conjured up and exaggerated as rationales to justify the continuation of a systems development in which substantial resources and bureaucratic capital have been invested (II-B, II-C). If the nature of the Soviet/Russian threat has truly changed, and if Russian military research, development, and production lines lie in a shambles, then it is hard in an era of scarce resources to justify proceeding with the F-22 program solely on the basis of that threat. On the other hand, traditional prudence in military planning -- minimizing uncertainty by practicing the routine behavior of assuming worst-case scenarios (III-A) -- would dictate going ahead with the F-22 "just in case."

There is no question that the Air Force has practiced traditional organizational behaviors, however, as the development of the F-22 has progressed. In a manner starkly reminiscent of the F-15, the F-22's specific characteristics
seem to have been determined largely due to the Air Force's overwhelming desire to protect it from inter-service "jointness," to keep its prized aircraft a single-service vehicle. The Air Force consistently, in efforts to protect its organizational "turf" against intrusions from the Navy and the Office of the Secretary of Defense (III-B), went to great lengths to argue that the unique requirements for the F-22 would be unsatisfied by any other aircraft (at first, the Navy's ATA, and later upgrades of existing Air Force planes and the Navy's A/F-X). This line of reasoning prevented the Pentagon, which was pushing for aircraft commonality in order to save money, from forcing the Air Force and the Navy to share the same weapon system. Indeed, the service pressures against commonality were so strong that the Air Force and Navy habitually collaborated to convince the Congressional Armed Services committees that their respective aircraft had been designed for completely different missions and therefore could never be successfully combined into a joint procurement effort. This common front helped each to protect its own core programs. Such behavior, where organizations form coalitions in order to pool resources (in this case, political resources) in order to maximize their bargaining position, is predicted by organization theory (III-D).

The Air Force has practiced several other classic organizational strategies in order to protect the F-22, some of which have had critical effects on its fundamental
characteristics. In order, for example, to get the aircraft into the procurement pipeline early and therefore ensure that Congress would be reluctant to cancel the program because such a substantial block of funds had been invested in it, the Air Force froze what was then the ATF's design in late 1987. This desire to shepherd carefully a core program through the system (III-B) meant that the F-22 eventually embodied far less advanced technology than would otherwise have been the case. Also, the service has marshalled its monopoly on tactical and technical resources with tremendous effect (III-D). During both the Major Aircraft Review and the Bottom-Up Review, the possibility of designing alternatives to the F-22 on the basis of existing aircraft was explored on the basis of data which were supplied exclusively by the Air Force -- making it certain that the F-22, the Air Force's preferred alternative, would emerge as the only viable option. The Air Force even quelled discussion of a potential new program in 1991, the Multi-Role Fighter, until the F-22 development contract was safely concluded. The service's desire to protect its key program (III-B) in this case is an unmistakable parallel to the earlier situation with the F-15 and F-16. Finally, the F-22 has been most recently protected through the Air Force's willingness to expand its basic missions to include air-to-ground capability, which could be interpreted either as a rational response to the lessons of the Persian Gulf War (I-A, I-C), or as a brilliant bit of organizational maneuvering by
the Air Force (III-B) -- or a combination of the two.

As was the case with the F-15 and F-16, the F-22’s prototyping procurement strategy was explicitly chosen in order to minimize the chances of repeating past procurement disasters, specifically that of the F-111. The Pentagon exhibited innovative behavior in order to prevent a recurrence of previous failure (III-E). The choice of the prototyping strategy had dramatic implications for the eventual shape of the F-22, since the explicit attention to risk-aversion meant that the YF-22 vs. YF-23 competition was to be judged not according to absolute superiority of prototype capabilities, but by which contractor best lived up to its predicted performance. In other words, the Air Force was searching for contractor credibility -- and therefore the likelihood of avoiding embarrassing failure that might jeopardize the program. Had the selection criteria been different, so might have been the prototype design choices and the outcome of the prototype selection process.
Chapter Six:
The Paper Tiger?:
Fulcrum, Flanker, and Soviet Weapons Procurement
In "The Good Old Days"

In a pattern similar to that of the United States, activity relevant to the early stages of fighter aircraft development during the Cold War period responded primarily to broad stimuli from the international environment -- in other words, to performance norms. Decisions to procure specific aircraft at a given point in time also stemmed from specific international stimuli, in this case specific information about the Western systems which the Soviet aircraft would be forced to counter in combat.

As predicted by theory, however, the end of the Cold War -- and hence the end of the stability and predictability of the international environment -- have changed the nature of the early stages of weapons procurement in the former Soviet Union. Under conditions of vastly reduced resources for defense, the nature of the threat ill-defined, and attention diverted away from threat assessment and toward the more urgent priorities of short-term organizational survival, early system specification and definition is now dramatically affected by domestic political and economic factors.

The later stages of the procurement process, during which the weapons systems are designed and development, are dominated in the Soviet case by domestic-level factors in both the Cold War and post-Cold War periods. In contrast to the
American cases, however, in the Cold War period the dynamics of the Soviet domestic political processes are driven by the incentives and motivations impinging on the defense industry, not the armed services. The Soviet military leadership consistently could not successfully command implementation of design and production of exactly the weapons system specifications it desired. Indeed, the Soviet Air Force and other military services habitually set quite sophisticated technical requirements for new weapons systems, only to have those requirements circumvented and ignored by design bureaus and production associations anxious to meet their targets for quantitative output, and hence equally anxious to avoid serious regard for product quality. As will be described in detail below, Soviet arms designers and producers were able to get away with such behavior because of their monopoly position; the services, their customer, had nowhere else to turn.

In the post-Cold War era, however, with high political priority no longer afforded to the defense sector and the old industrial system largely dismantled, the defense industries have had to resort to sometimes desperate coping strategies literally in order to continue to exist. In this environment, organizational politics, and frequently the personal political skills and connections of individual industry representatives, have dominated what little weapons production and design is still taking place.
This Soviet case study focuses on the procurement of the two most recent-generation Soviet fighter aircraft, the Su-27 and MiG-29. When information has proved to be scarce on these particular weapons systems, the data net has been cast more widely to include other specific systems, services other than the Air Force, and the Soviet weapons procurement process as a whole.

Broad Threat Dictates a New Requirement

In the pre-Gorbachev period, the requirements-setting phase of weapons procurement was dominated by external, or international systemic, factors. More specifically, this phase was governed by a "rational actor"-type response to the needs of the perceived tactical and operational situation, and then additionally an "action-reaction"-like answer to the carefully-monitored technical developments in the West.

The Soviet Air Force specifications for the fighter aircraft Su-27 and MiG-29 were set in the early 1970's in response to the lessons learned from the experience of air combat in the Vietnam and Middle East Wars. During the Vietnam War, South Vietnam and the United States primarily flew F-4 Phantom fighters to escort bomber raids into North Vietnam, while the North Vietnamese were equipped for air combat with Soviet-supplied MiG-17's and highly maneuverable

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1 Where not otherwise cited, the data in this section are based on interviews with Soviet/Russian aircraft designers.
MiG-21's. The Soviets diligently took note of the fact that the F-4, which had been conceived in the 1950's and 1960's to maximize speed and altitude, suffered considerable losses to the MiG-21 because of its lack of maneuverability. The F-4 had been constructed mainly for intercept of fast bombers in bad weather or at night; its large wing loading prevented rapid turn capability, and hence rendered it unable to outfox its more maneuverable opponent in a dogfight. In fact, after the MiG-21 appeared in April of 1966, American fighter losses increased. In the first three months of 1966, 11 U.S. aircraft were lost, as compared to 9 North Vietnamese, for a ratio of 1.2:1. From May to December of that same year, however, after the MiG-21 entered the picture, the United States lost 47 aircraft, compared to North Vietnam's twelve. The ratio had increased to 4:1.

Before Vietnam, American fighter tactics focused on the use of radiolocation systems to intercept and track the enemy, and then the use of guided air-to-air missiles fired from beyond visual range to destroy him. Automatic control systems therefore received the bulk of aircraft designers' efforts. This philosophy repudiated the idea of maneuver battle, denigrating the role of pilot input and the capabilities of the pilot.²

It soon became clear to both the Americans and the Soviets that excessive reliance on long-range air-to-air missiles was a mistake. The experience of air combat in Vietnam rapidly demonstrated that for every 11 launched Sidewinder-type missiles, only one reached its target, and that in order to fire at all it was necessary for fighters to maneuver into an optimal launch position directly behind the target. Fighter designers therefore came to the conclusion that air-to-air missiles could not completely replace gun-type weapons with large ammunition loads. Meanwhile, the North Vietnamese fighter crews, trying to break through the American fighter screens set up around the bombers, employed intermittent ambush tactics rather than massed strikes. These carefully planned surprise attacks, based on rapid maneuver capability, were the essential to the success of the North Vietnamese strategy. As a result, the American pilots could not take successful countermeasures; the MiG-21’s maneuverability more than counterbalanced the numerical superiority of the F-4 Phantoms. The Soviet Air Force diligently learned the lesson that within-visual-range dogfighting, requiring high maneuverability, was the wave of the future in fighter aircraft, and conceived the Su-27 and

3 A. N. Ponomarev, Aviatsiya Nastoyashchego i budushchego, Moscow, Voyenizdat, 1984, pp. 47-60.

MiG-29 accordingly. In terms of specific requirements, according to one Soviet designer, meant dramatic increases in thrust-to-weight ratio (> 1.0), a moderate wing loading factor (300-350 kg/m²), and new engine design developments, particularly a gas temperature of 1650 K before reaching the turbine. Only these characteristics would enable an aircraft to maintain superiority in speed entering and exiting the battle area, and give it the capability to engage the enemy without losing altitude.

The importance attached to maneuverability is also revealed in one particular series of Soviet military journal articles which presents a mathematical model for measuring

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6 Interviews.
prospects of success in air combat:  

\[ L = \left[ \frac{(P/G) \times SEP \times T \times M \times Bd \times Si \times N \times Wa^3 \times B^4}{(G/S)^2 \times Cr} \right], \]

where

- \( L \) = capability of aircraft to carry out air combat tasks;
- \( P \) = engine thrust;
- \( G \) = flight weight;
- \( S \) = wing area;
- \( SEP \) = Specific Excess Power, or surplus thrust-to-weight ratio;
- \( T \) = braking/deceleration capability;
- \( M \) = effect of mechanization of wings;
- \( Bd \) = controllability/handlability of aircraft;
- \( Si \) = stability of aircraft;
- \( N \) = individual defense (invulnerability);
- \( Wa \) = capabilities of warning apparatus (defensive electronics);
- \( B \) = weapons characteristics;
- \( Cr \) = dimensions of aircraft;
- \( P/G \) = thrust:weight ratio; and
- \( G/S \) = wing loading.

From this equation several things are clear. The first is that the quality of defensive electronics and weapons systems are quite important, being raised to the third and fourth powers, respectively, in the equation. When all the remaining factors relating to maneuverability are combined, however, it becomes evident that maneuverability concerns are also utmost in the author’s mind. These factors -- \( P/G \), or thrust-to-weight ratio; \( G/S \), or wing loading; and \( M \), or wing mechanization -- when taken together equal a weapons system characteristic taken to a fourth order or magnitude. In other

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7 Col. V. Kirillov, "Sovremennyy istrebitel’ v vozduishnom boyu," Zarubezhnoye Voyennoye Obozreniye, February 1979, pp. 53-60; March 1979, pp. 43-49.
words, maneuverability considerations assume equal importance to the characteristics of weapons systems in this formulation.

Thrust-to-weight ratio can be viewed as a measure of an aircraft’s capability for rapid acceleration on any trajectory, including the vertical. A high thrust-to-weight factor is particularly important in the beginning and final stages of an air battle, when a rapid gain of speed or altitude is demanded for approach toward or disengagement from the enemy. The aircraft with the larger thrust-to-weight ratio can, for example, choose the height and speed at which he will carry out an attack, rather than permitting the enemy to dictate that to him.

Wing loading is the ratio of the aircraft’s weight to the surface area of its wings. It is an indicator of the rate at which an aircraft can turn; according to Soviet calculations, about 85% of a desired increase in angular velocity is achieved with a decrease in wing load, and only about 15% through increased thrust. Rapid and tight turn capability is particularly important in the midst of air-to-air combat. Thrust-to-weight ratio therefore determines whether or not the enemy will be engaged under optimal conditions and hence destroyed; the wing load factor determines the survivability of the fighter in combat.

Designers at the Sukhoy Design Bureau have also been forthcoming in describing the broad operational environment in which the Su-27 would be used. Soviet war plans stressed the
need to counter any airborne invasion as far away from the homeland as possible -- that is, over the skies of Germany, not Poland or Ukraine. To achieve this goal, Air Force planners knew they needed the ability to engage NATO tankers and AWACS aircraft deep in NATO airspace. The Su-27 therefore had to penetrate far into enemy territory, through swarms of unfriendly fighters, in order to kill NATO's command and control "brains."  

It was not just maneuverability, but also radar systems that Soviet planners realized had to be incorporated into a new aircraft. One MiG-29 pilot describes Soviet reasoning as follows: during the air war in Vietnam, the Soviet-installed air defense system had cost the Americans literally hundreds of fighter-bombers. The Americans had to adopt new tactics in order to counter radar-controlled high- and medium-altitude surface-to-air missiles deployed in concentric circles around valuable targets. They learned to fly under Soviet radars in small, dispersed formations, arriving at different headings simultaneously to saturate the defense forces. The Soviets could only assume that the United States would apply the same tactics to attack planning against the Soviet Union itself, effectively neutralizing Soviet air defense missiles and

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interceptors directed to their targets by radar controllers on the ground. Those interceptors, the Su-15 and MiG-23, had relatively weak on-board radars and fire control, and on-the-ground battle management officers could not possibly detect and track F-16s moving supersonically at low altitudes. Airborne radars up until this point had been designed to deal with high-altitude threats. In short, the Soviet Union needed new fighter aircraft with pulse-Doppler radar, which could detect a low-level aircraft against ground clutter and manage a look-down, shoot-down fire control system.

Other operational requirements for both the MiG-29 and Su-27 had to do with the specific environment in which the aircraft would be used, and the personnel who would be using them. The Soviet Air Force's requirement for the aircraft to be capable of operating from unpaved runways led to the adoption of a new system to protect the engines against the risk of damage from ingesting foreign objects.\textsuperscript{10} During taxi and take-off, the air intakes are closed off by internal doors, with engine air provided instead by upper auxiliary inlets.

The design and development process also emphasized design solutions which would allow inexperienced pilots to operate

\textsuperscript{10} See "MiG-29: A First Class Solution For Air Defense," advertisement placed by the Moscow Aircraft Production Association (MAPO), Military Technology, August 1993, pp. 58–64.
the aircraft effectively."\(^{11}\) For example, the cockpit layout is the same for the MiG-29 and Su-27, so that pilots can switch from one to the other with relative ease.\(^{12}\) In addition, just in terms of the powerplants, the MiG-29 failure situations can be overcome with simple procedures: it can be flown and landed with only one engine running; in case of complete failure of both generators of the electrical power system, the aircraft can be flown for a considerable time using on-board storage batteries; failure of the air intakes control system does not result in a loss of engine stability; and in case of a complete failure of the electronic control systems of both engines, alternate hydromechanical backup systems exist. The engines can be restarted in flight over an enormous range of conditions, from an airspeed of 350 km/hour up to 1,500 km/hour, and up to an altitude of 12,000 meters at low speeds and at any altitude at high speeds. One Sukhoy designer was particularly forthright: "The primary design law that we must follow is that we must design for a fool."\(^{13}\)

\(^{11}\) This philosophy also extends to operations and maintenance personnel (see Zuyev, 1992, pp. 136-137) and is true of Soviet combat aircraft other than the fighters discussed directly here. See Col. Vitaliy Moroz, "Su-25TK: Shturmovku utochnyayut zadachi," Krasnaya Zvezda, 11 November 1992, p. 2.

\(^{12}\) Halberstadt, MiG-29, 1992, p. 69.

\(^{13}\) Interviews.
A Specific Threat Dictates Requirement Definition: Responding to the F-15

The Soviets closely observed that the Americans were learning these same lessons about maneuverability; the Soviet Air Force literature particularly dwells on the fact that the next generation of American fighters, the F-14, F-15, F-16, and F-18, essentially eliminated the defects from which the F-4 suffered in Vietnam. The main feature of the new American fighters, as emphasized by Soviet sources, was not just a growth in their practical ceiling, maximum speed, and combat load (all of which were adequate in the F-4), but also in high energetic maneuverability. Wing loading factors decreased as dramatically as thrust-to-weight ratios climbed, decreasing minimum turn radii and increasing maximum angular velocities. For example, the turn radius of the F-16 at average altitude is less than half that of the F-4. Similarly, the F-15, in the Soviet view, was constructed deliberately to eliminate the fatal flaws of the Phantom. Table 6.1 demonstrates the Soviet comparisons of relevant aircraft specifications.

Rather than jumping headlong into designs of their own, therefore, the Soviets waited to gauge the Western interpretation of the new tactical requirements, and then designed their next

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14 Koleshnikov, p. 56.
Table 6.1
Comparison of F-15 and F-4 Characteristics

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>F-4</th>
<th>F-15</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thrust-weight ratio</td>
<td>0.88</td>
<td>&gt; 1.1</td>
</tr>
<tr>
<td>Wing loading</td>
<td>370</td>
<td>280</td>
</tr>
</tbody>
</table>

generation of aircraft in direct response to the Western analog. The idea, according to interviews with the chief designer of the Su-27, was not to copy American technology, but instead to wait until there was concrete evidence of a threat to respond to, and then to construct a system meticulously around that specific threat in order to defeat it -- "without the F-15, there would never have been an Su-27; without the F-16, there would never have been a MiG-29."  

M. P. Simonov, now Chief Designer of the Sukhoy design bureau, admits that the F-15 was taken as the starting point -- a "rival" -- for the Su-27. Another prominent designer explains that the Soviets waited until the five competing designs in the American F-15 competition were published, and McDonnell Douglas given the winning contract in 1972, before

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16 Interviews with Soviet aircraft designers. See also A. Gorokhov, "MIG-29: vperвые na wystavku," Prayda, August 14, 1988, p. 3, for interviews with a Mikoyan test pilot, Mikoyan designer, and the head of the Ministry of Aviation Industry, all of whom echo this point.

they even considered going ahead with their next generation fighter design. Soviet designers explain that they must work this way because the Soviet Union does not have the resources to expend on many varieties of experimental aircraft, as is the case in the United States; they must therefore target their resource consumption very carefully against a very specific threat. At that time, the chief of the Central Aero- and Hydrodynamics Institute (TsAGI) approached the Sukhoy design bureau and confirmed that a response could now be planned since American intentions were known.\textsuperscript{18} In particular, targeted decisions were made to improve on the performance of the F-15 in the following ways: increase the range (F-15, 2030 km; Su-27, 4000 km), and give the Su-27 better weapons including completely new, different missiles and a better aiming system.\textsuperscript{19}

In fact, according to Simonov, during the design of the Su-27, data from F-15 specifications were put into the Sukhoy design bureau's computers and played out in specific competition with Sukhoy's initial design model. The Sukhoy

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\textsuperscript{18} Interviews. In fact, one designer was quite explicit about the degree to which the Soviet Union "will not produce an aircraft until [we] know what the U.S. has decided to develop. Therefore,

* the SU-24 is the Soviet answer to the F-111;
* The Su-25 is the Soviet answer to the A-10;
* the Su-27 is the Soviet answer to the F-15;
* the MiG-29 is the Soviet answer to the F-16;
* the MiG-31 is the Soviet answer to the B-1B, being designed to move in the B-1 operational area and equipped with 16 missiles to shoot it down.

\textsuperscript{19} Interviews.
design at first won repeated trials at an (unspecified) ratio of 1.35:1. In accordance with that concept, which was clearly based on response to and attempts to outdo the Western counterpart, the first Su-27 prototype (known as the T-10) was built. Around the time of its first test flight in the summer of 1977, however, according to Simonov, updated data input from various Su-27 design modifications fed into the design bureau's computers caused the ratio to reverse; the F-15 was now defeating the Su-27 at that same 1.35:1 ratio. At that point, solely in response to the correlation of data compared with the F-15, Simonov determined that his design bureau had produced a "mediocre aircraft," and went to the Ministry to request additional time for a complete redesign\(^{20}\).

Su-27 Design History

According to then-Sukhoy designer Oleg Samoylovich, the Su-27 started in 1971 as a series of specifications and a general outline of what the aircraft would look like:\(^{21}\)

* the use of fly-by-wire flight controls, because Samoylovich wanted the result to be an aircraft that was unstable in the longitudinal axis;

* an integral wing-fuselage layout, based on extensive comparison studies of classical layout (separate fuselage and wing sections) and integral layouts with a blended fuselage-wing and engine nacelles below the wing;

* the most efficient possible ratio of lift to drag; and

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\(^{20}\) See interview with Simonov in Igor' Andreyev, Boyevvyye Samolety, Kniga i biznes, Moscow, 1992, p. 148.

\(^{21}\) Halberstadt, Su-27, p. 31.
* air intakes under the wings, since the requirement was for a very agile aircraft, and one with very stable airflow at the engine intakes at any angle of attack.

An accident in the development of the Su-25 influenced the layout of the engines and engine nacelles in the Su-27.\textsuperscript{22} There was a flameout during a Su-25 test flight, after which the air intake broke apart and separated from the airframe, taking a large portion of the wing and the horizontal stabilizer with it. As a result, Samoylovich vowed never again to design an aircraft with only one engine. He also decided to lay out the engine nacelles such that the failure of one powerplant would not damage the other or threaten the airframe.

In addition to these basic ideas, as described above, Samoylovich and the other Sukhoy designers also waited for the results of the American F-15 competition. At first, Chief Designer Pavel Sukhoy, did not want to design an Su-27 type aircraft. He resisted for about six months, arguing that with Soviet inferiority in electronics in terms of size, weight, and reliability, the design bureau could not produce an aircraft the same size as the -15. He changed his mind, however, after preliminary studies and wind tunnel tests showed that Samoylovich’s design could achieve extremely high lift-to-drag ratios, in the neighborhood of 12.6:1.

Once Pavel Sukhoy was on board, and after two years of preliminary work, the bulk of the Su-27 design was a product of a weekend design binge by three Sukhoy engineers, Samoylovich, Valery Nickolai, and graduate student Vladimir Antonov\textsuperscript{23}. They claim they worked over the weekend because of the volume of interruptions they suffered during working hours.

It was Western research on S-shaped and "Gothic" wings that convinced the Sukhoy design team that fly-by-wire flight controls would be necessary. That research helped them understand that a strong vortex was created by leading-edge extensions, and as a result, the aircraft would be unstable in the longitudinal axis. In other words, the price of high lift and high angles of attack was instability in the longitudinal moment. Fly-by-wire and computerization of the flight controls were the only solution. Samoylovich realized at the time that this was a high-risk answer to the problem, but earlier experience with the Sukhoy T-4 aircraft, a Soviet fly-by-wire aircraft design in 1967, lent him confidence that the risk would pay off.

When the designers made the first general layout sketches, it became apparent that the internal volume of the aircraft would be much larger than necessary to fulfill the Air Force's range requirements. The Air Force wanted 200 km

\textsuperscript{23} Antonov's graduate project at the Moscow Aviation Institute was to research the integral fuselage-wing layout. See Halberstadt, \textit{Su-27}, 1992, p. 35.
more than that projected for the F-15, implying a range of 2,500 km, but Samoylovich saw that the Su-27 could easily hold sufficient fuel for 3,300 km, possibly even 4,000 km. When the maximum g-load on the airframe was calculated, however, using the standard Soviet load of 80 percent of maximum internal fuel, it appeared that the range requirement would dictate a very strong, perhaps very heavy, airframe. The Soviet Air Force deputy commander for acquisition, Col. Gen. Mikhail Mishook, responded positively to Samoylovich’s solution: put the additional fuel in an external droppable tank. For the strength analysis computations, the weight of internal fuel sufficient only for the 2,500 km range would be used. This decision introduced the concept of dual design weights, one for high g-loads, greater maneuverability, and shorter range, and the other for lower g-loads and maneuverability, and longer range.24

Simonov, having taken over as General Designer after Pavel Sukhoy’s death, was in charge of the prototype design. His primary modification from sketch to prototype was to lower the drag by reducing the area of the center section of the aircraft. The airfoil was also changed from a slightly drooping leading edge to one that was flatter for better maneuverability, which reduced the lift to drag ratio; leading edge flaps were introduced to solve that problem. Finally, an earlier decision to add ceramic to the engine turbine blades

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could not be realized; the technology to reduce the turbine inlet temperature by the required degree had not yet matured.

In the summer of 1977, Sukhoy test pilot Vladimir Sergeyevich Ilyushin took the T-10 on its first flight. All systems performed as anticipated, and therefore the designers went ahead with the foundations for twenty additional test aircraft right away, without waiting for more extensive analysis of the first flight. Su-27 designers are still at a loss to explain why the T-10 did not perform up to expectations; they speculate that they had misinformation fed into their initial analysis of the capabilities of the F-15, and that the lack of the promised breakthrough in engine technology led their initial Su-27 performance projections to be overly optimistic. Whatever the cause, Sukhoy personnel came to the conclusion that they had built a technologically mediocre machine which did not achieve world levels in range or maneuverability. Serious financial losses were incurred, since 20 prototype aircraft had been built using a configuration that turned out not to be suitable for series production.

When informed of the situation, several top officials of the Ministry of Aviation Industries were not supportive, but then-Deputy Minister Ivan Stepanovich Silayev same to the design bureau’s rescue. Sukhoy designers started over, once

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again determined to design an aircraft that would be technologically superior to the F-15. Samoylovich argues that the delay actually saved time and resources for the design bureau. First of all, the extra time allowed component development to catch up with airframe development; the 20 defunct prototypes were used as flying testbeds for the radar, avionics, control systems, and other subsystems (even with the delay, the first 12 Su-27s were tested with Su-24 engines because the new ones were not yet ready).\textsuperscript{27} When the redesigned airframe was finally delivered, the component systems were ready at the same time. In addition, further wind tunnel testing on the new airframe revealed that the aircraft would not spin at low speeds and high angles of attack, thereby enabling designers to add more maneuverability at higher angles of attack because of the safe stall characteristics. That raised the permitted $g$-load from eight to nine, and allowed the gross weight to be much higher.\textsuperscript{28}

As the design evolved, according to Samoylovich, subcontractors began to deliver equipment, meant for installation in the nose of the aircraft, that failed to meet weight specifications. As a result, the aircraft’s center of gravity was moved forward, making the aircraft stable. The Sukhoy designers responded by moving the center of lift forces forward; although they did not anticipate better flight

\textsuperscript{27} Interviews.

characteristics than their original design, to their surprise and delight, the change resulted in additional lift from the foreplane and improved lateral stability characteristics.

MiG-29 Design History

The MiG-29 is an air superiority aircraft, designed for control of the skies within its combat radius. The Mikoyan Design Bureau describes its basic missions as all-weather, 24-hour counter-air, close air support, and counter-air reconnaissance.29

Literally dozens of forerunners to the MiG-29 concept floated around the design bureau for several years in the early 1970's; the project was finally formalized into a specific technical and tactical requirement in 1972, with funding and a schedule.30 The concept was a response to changes in NATO tactics and aircraft, specifically the need for enhanced maneuverability and new types of radar described earlier. The specifications meant that the new aircraft would need new engines, avionics, construction materials and techniques, and particularly, a new aerodynamic shape.

Initial test prototypes had fin extensions which were deleted in the production aircraft. Much of the airframe design has to do with the MiG-29's mission constraints. Its


sophisticated radar imposes size and shape requirements on the aircraft's nose, and its dogfighting and slow-speed agility require massive control surfaces and widely spaced vertical stabilizers.\textsuperscript{31}

The MiG-29 first flew in October 1977, with chief test pilot Alexander Fedotov in the cockpit.\textsuperscript{32} Thirteen prototype aircraft were dedicated to the test program, which was conducted at an air base near the town of Ramenskoye, outside Moscow. The first prototype was used for general evaluation of the aircraft; it was the only version built with the nose gear well forward. The second prototype was devoted to engine testing. When one of the engine mounts broke on 16 June 1977, the aircraft caught fire and test pilot Valery Menitsky had to eject. He emerged safely, but the airframe was not salvageable; the designers learned valuable lessons about engine mount strength requirements. Other prototypes were dedicated to testing radar, fire control, flight characteristics, structural load handling, and other engineering concerns. The fourth of these also caught fire and was abandoned in flight, this time by Fedotov. The test pilot squadron at first consisted of an informal group only from Mikoyan; Soviet Air Force pilots joined them later in the program.

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\textsuperscript{31} Halberstadt, 1992, p. 34.
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\begin{flushright}
\textsuperscript{32} Details of the flight test program are from Halberstadt, 1992, pp. 46-47.
\end{flushright}
Early in the MiG-29 flight test program, the test pilots discovered that the aircraft stalled quite easily. Tremendous demands are placed on a maneuverable fighter during close engagements -- flight straight up and down, at maximum and minimum speeds and at extreme angles. The end game, pointing a gun or missile at an enemy, often requires a fighter to risk stalling and spinning. The first copies of the MiG-29, however, could not handle these risks, becoming uncontrollable when power and angles of attack were increased. The designers responded with the addition of tiny vortex generators to the nose of the airframe, right at the base of the pitot tube, so that enough airflow would be deflected to the control surfaces at stall speeds to provide control authority.\textsuperscript{33} These vortex generators, along with a stall-prevention system that can be overridden, a computer-driven stability augmentation program, and another computer program that adjusts the deflection of the controls based on airspeed and angle of attack, made the MiG-29 virtually spin-proof; if a pilot forces it into a spin, it will fly itself out once he stops forcing. In other words, the flight control system was designed to make the aircraft as easy and safe as possible to fly in combat.

The first deliveries of the MiG-29 to the Air Force were made in 1983. It was produced in several factories, including the Labor Banner factory in downtown Moscow.

\textsuperscript{33} Halberstadt, 1992, p. 49.
The Impact of Organizational Interests and Needs: Soviet Weapons Design and Procurement

Once the requirement was defined, starting the flow of resources to the project, the Soviet weapon system began its way through the design and production pipeline. Any serious student of the Soviet economy is familiar with the standard litany regarding the restraints on technical innovation in Soviet industry. While the privileged position of the defense economy insulated it from a few of these factors, it nonetheless suffered from many of the more perverse effects.\textsuperscript{34} For the purposes of this study, some of those effects will be summarized here, and then the recent evidence of their impact on the defense sector will be reviewed.\textsuperscript{35}

Decision Rules: In terms of the goal-oriented models of organization theory, what happened in Soviet industry was that the central economic planners were not able successfully to subdivide their overall goals of innovativeness, efficiency, and productivity into subroutines that actually produce the desired behaviors. The decision


\textsuperscript{35} Much of the following discussion on supply, pricing, and decision rules is taken from Joseph S. Berliner, \textit{The Innovation Decision in Soviet Industry}, MIT Press, Cambridge, MA, 1976.
rules governing the players in Soviet industry actually mitigate against innovation and quality. Soviet military industry, just like the rest of Soviet industry, operated according to annual and five-year plans. For example, the "target rule" dictated that the size of the factory's bonus depended not on the absolute value of output, but on the ratio of produced output to the plan-output target. The lower the plan target, the larger the bonus for a given volume of output produced. The incentive structure therefore directed management to build a "safety factor" into the enterprise plan by seeking to have plan targets set at minimally defensible levels. Innovation was resisted because it tended to reduce current rates of output. A short time horizon reigned.

Also inhibiting the risk of technical innovation was the "ratchet effect," in which planners regarded performance in any period as the revealed minimum level of that enterprise's capability in the next period. Management therefore tried to select an optimal, not a minimum, degree of overfulfillment of plan targets. The system severely penalized non-plan fulfillment, but only slightly rewarded plan overfulfillment. If innovations were actually incorporated into the plan, then the ministry might have been persuaded to modify targets for gross output and cost reduction, and the risk of encountering supply problems was smaller. Innovations conceived during the year were therefore shunted into a "hold" file, where they waited to be proposed for a future plan period.
Supply System: Another of the biggest organizational factors inhibiting Soviet military-technical innovation, not only in weapons design but in the industrial economy as a whole, was the supply system. Innovation involves changes in the production process, which requires a corresponding change in the pattern of inflow of inputs, specifically new materials with which the producer is unfamiliar. This required establishing new sources of supply, a great risk in a taut planned economy of perpetual shortage. The new supplier may also be unfamiliar with the procedures and needs of the customer. Interenterprise supply was one of the major shortcomings of Soviet economic organization. Avoiding innovation minimizes supply uncertainty. The noninnovator, over time, became comfortable with his established suppliers, the ministry and government agencies who issue allocation certificates, and the marketing officials in the supplier enterprises. He had also probably legally or illegally stocked working supplies of materials which he historically had trouble getting, and did not want to let those go to waste. These phenomena correspond to the classic stability models of organization theory. Standard operating procedures relevant to the old supply lines became comfortable and ingrained; enterprises were unwilling to take the risks involved with establishing new lines.

The formal estimates of supply requirements for an enterprise were made far in advance of the time supplies were
actually used. A year's supplies were based on a draft plan
drawn up in the summer of the preceding year. An innovating
ternational enterprise may have required an instrument or piece of
equipment that had not been anticipated then. Since no
statement of requirement had been submitted, the enterprise
had no allocation certificate for that commodity. Also, an
interruption in supply flow may have led to lower output
rates, and perhaps an underfulfillment of plan targets.

Finally, innovators often require special-order jobs or
relatively small quantities of various commodities. Soviet
suppliers regarded that as a nuisance and interference with
their own critical production tasks, and hence ignored such
orders, leaving innovators with inefficient in-house
production of such items as their only alternative.

*Horizontal Institutional Separateness:* The major element
of horizontal separateness is the isolation of applied
research from design and development. Soviet research
institutes constrained weapons design from the very beginning
by publishing handbooks that specified not only research
results, but also an approved list of structures, design
forms, components, materials, and manufacturing techniques.
The research institutes had a monopoly on the largest wind
tunnels, test rigs, etc., as well as the most highly qualified
scientists. The design bureaus therefore had to rely on the
handbooks to supply day-to-day guidelines on design.\textsuperscript{36}

This structure was intended to ensure producibility, maintainability, and ease of production.\textsuperscript{37} There was an emphasis on strict adherence to design and development schedules, which encouraged technological conservatism on the part of designers once the decision was made to proceed with the development of a weapon, ensuring a high probability of development success. All of these factors added up to encourage standardized design procedures. The separation of applied research from development meant that the designer would only take from the research institute whatever was available, and would not wait for something new. There were no "buy-ins," and therefore no incentive for fancy designs in the applied research stage. The research institutes often did not provide usable output to designers, and were often not aware of the problems of design. Design bureaus in turn often did not turn producible designs to production plants. Plants often complained that the first year or so of preparation for production was taken up by the conversion of the design into a workable product that could be produced.\textsuperscript{38}

The designers had to be confident that the chosen technical levels did not present insurmountable design or


\textsuperscript{38} Alexander, "R&D in Soviet Aviation," p. 16.
production problems. The result was a de facto technical freeze on major system components before the weapon was developed. Designers were therefore inclined to employ entire subsystems from previous generations of weapons. This allowed the efficient continued use of older systems. Soviet designers commonly offset the drawbacks of this early technical freeze with subsequent improvement programs. The design bureaus therefore often simultaneously worked on new and modernized weapons systems in different stages of development. This discouraged designers from promoting unduly risky approaches to solving technical problems.

The old administrative system also led to a situation in which enterprises and production teams in different ministries and departments were completely isolated from one another; they did not know often even of each other's existence, let alone of each other's design and production capabilities. New breakthroughs were not communicated among the ministries, and therefore each separate unit spent a great deal of time reinventing various wheels. Because of the unreliability of supply chains run totally from the center, all of these isolated units also strove essentially for autarky, producing all of the parts they might need in order to fulfill their production requirements in-house.39 This "A to Z" approach to

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manufacturing even went to far as to include the on-site production of nuts and washers at facilities supposedly devoted to the final assembly of entire engines. Of course, this method of production, entailing the production of parts in small quantities "almost as though they were handicrafts," was expensive and grossly inefficient, foregoing any benefits from economies of scale.

The "Val," or Gross Output, Problem: Soviet industrial producers were paid under the old standards of "val," or gross output, along the lines of simple quantitative plan fulfillment and "dispatch" of product, rather than for quality, reliability, or product mix of output. "Val" is shorthand for "valovaya produktsiya," or gross value of production. It expressed the total value, at fixed prices, of the entire output of an enterprise, regardless of whether the product found a buyer. There are several obvious negative consequences to this as a primary economic indicator:

* It includes the value of supplies produced in other enterprises, and so it pays to use more expensive inputs.

* It discourages enterprises from producing less expensive items, since this would decrease the value of gross output. This, of course, ignores demand.

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* It includes products made and not sold, failing to penalize output "na sklad" ("for the storeroom"). These items are not wanted and simply sit in storage, but are clocked up for the producing enterprise in terms of "val." 43

* It affects the pace of technical innovation. When gross output is the primary orientation of an enterprise, managers will be hesitant to interrupt production in order to introduce an advanced technology for fear of falling short of output targets. On those occasions when technology is incorporated, the incentive is for it to involve the most expensive equipment possible, leading to a large increase in "val" indicators. The Soviet experience has been that the productivity of new machinery is generally an insignificant increase over that which it replaces, but its price is several times higher, raising costs and therefore output indicators for the enterprise. There is little concern for potential benefits in quality and efficiency from the new equipment.

Again, the ministries and other planners did not succeed in constructing organizational subgoals to match the overall goal of innovative behavior. These gross output indicators

43 Over the last 25 years, almost one-third of total work time in the Soviet Union has been "na sklad." These goods are stored and never used, generally because their quality is so bad. This leads to the growth of materials stocks and unused work places. In 1985, the total value of wasted goods not in economic use was 436.5 billion rubles. One particular example is also illustrative. The Frunze Agricultural Machine-Building Enterprise was for many years the only source of a certain aggregator. It produced 30,000 of these aggregators per year, even though there was only park space in the entire country for 2,000 - 3,000 of them. This is the epitome of quantity for the sake of quantity, with no regard for quality or demand. See S. Gubanov, "Istoki zatratnogo podkhoda i vozmozhnosti ego preodoleniya," Planovoye khozyaystvo, No. 4, April 1988, p. 99; N. Snezhkov, "O nekotorykh usloviyakh protivozatratnogo podkhoda," Planovoye khozyaystvo, No. 11, November 1988, pp. 103-104; V. Mel'nik-Khmaryy, "Khozyaystvennyy raschet protiv zatratnogo podkhoda," Planovoye khozyaystvo, No. 9, September 1988, p. 108; and S. Gubanov, Yu. Perevoshchikov, and V. Sis'kov, "Ot zatratnosti k potrzebnostям," Planovoye khozyaystvo, No. 1, January 1989, p. 108.
continued to wreak economic havoc even during the profit- and contract-oriented reforms of the late 1980s, because there existed many different targets for each enterprise, in the tens or even hundreds: output, contract fulfillment, labor productivity, finance (costs, expenditures), capital construction, technical progress, inputs, etc. It was impossible to keep track of them all, and usually several of them conflicted with one another. For example, an enterprise could not increase quality of output while simultaneously reducing the use of certain key inputs. Similarly, it could not introduce certain technologies while consistently increasing the output of certain affected products. While planners may have insisted on other goals, usually decreasing costs and increasing efficiency and productivity, the ministries, who were the real hierarchical bosses, still focused on gross output. The ministries had no choice but to adopt this orientation, since they supervised a vertically integrated production structure in which the outputs of one organization were the inputs of another. They had to insist on the satisfaction of gross output targets in order to keep supply lines functioning. The main enterprise targets therefore remained growth of total output, and output of key products.

**Pricing System:** The Soviet pricing system also inhibited innovation. Of interest here was the wholesale price received

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44 Nove, p. 103.
for a product sold to other enterprises, and paid for goods bought from other enterprises. Retail prices were simply wholesale prices plus a turnover tax and a retail markup.

Wholesale prices were determined by cost plus profit. Enterprise average costs were used here, defined as the product's average unit cost of production in every enterprise that produced it. Direct costs, generally wages and materials, were calculated not as amounts actually spent, but as those that should have been spent at a "normal" enterprise, based on official "norms." This structure was intended to force enterprises to keep costs down and to be productive. In actuality, it led to a set of prices reflecting the behavior of only the lowest-cost producers.

From enterprise average costs, branch average costs were calculated. These were the average of the unit average costs of all enterprises producing the product. The wholesale price was then simply the branch average cost plus a profit markup. The markup was intended to be large enough to cover the volume of profits required by a "normally operating enterprise," with the expenses to be covered including worker incentive funds and required payments to the state budget. Since prices were based on branch average costs, realized profits varied among enterprises in the same industry, depending on their product mix and the divergence of their costs from the branch average. The highest-cost enterprises may have realized zero profits or even a loss, requiring subsidies to keep them
solvent.

Prices were also relatively permanent, set without limit of time. They were changed only when the accumulated effects of past changes in cost and demand conditions caused the existing price structure to be excessively out of line with the existing cost structure. At that point, there may have been a general or partial revision of wholesale prices. This was done only sparingly because of the ripple effects into other sectors of the economy. Realized profit levels were therefore likely to diverge increasingly over time from the levels planned at the time prices were set. After a time, prices bore little resemblance to real branch average costs. New products were generally less profitable than older ones, because costs decreased over time, increasing the profitability of the older products. In addition, product innovations involve a series of costly expenditures, pushing up average costs. If all these expenses were not accounted for in the process of price setting, then the cumulative costs of innovation were an obstacle. One of the few ways a manager could hope to have his price increased was to contrive to have his product classified as "new," entitling him to a new price from the State Pricing Commission. A great deal of managerial ingenuity therefore went into the redesign of products with a minimum number of inexpensive, non-disruptive changes for the specific purpose of getting the product reclassified as new.
Impact on the Military: "Diktat" of Designers and Industry

Having summed the well-known impact of these factors, it is now reasonable to ask whether they affected the defense sector as dramatically as they did the civilian sector. The answer seems to have been yes. The conventional wisdom is that Soviet military industry produced higher quality output than the civilian sector because of the monopoly position of the customer, and hence the customer’s ability to demand higher standards and enforce rigorous quality control. Over the past several years, however, it has been revealed that the situation was more complex than that; the monopoly position of most defense enterprises allowed them as producers to respond to the vagaries of their own bureaucratic and organizational interests to a much greater degree than to the needs of the armed services. Their focus was on providing jobs for their workers, and fulfilling the ever-present gross output targets. Cost-effectiveness was not a concern, so that many competing systems were built to accomplish the same mission, and few trade-offs were made as material inputs were allocated to weapons producers.\(^45\) The resource dependency model of organization theory is illuminating here. A military service was often completely dependent on a single design bureau or production association for a weapon system. If it had no alternate source of supply, there was little it could do to

alter the structure of its situation. Former CIS Defense Minister Yevgeiy Shaposhnikov may have summed it best: "Nobody knew a budget, nobody took it into account. The bag was open -- you could grab as much as you wanted from it. Justify the expenses, and that's it."46

One manifestation of the "val" problem surfaces in accounts of the operations and maintenance records of the MiG-29. Russian spokesmen proudly trumpet mean time between failures (MTBF) detected on the ground and in flight of 7.8 hours, with combat readiness of units operating the aircraft at over 90 percent.47 But the degree and frequency of inspection of these aircraft, as specified in the standard manuals and operations documents, was actually a great deal higher than that required to maintain operational readiness and efficiency. Inspections were in fact conducted on a "val" basis, with little consideration given to containing personnel or equipment costs. Bonuses were earned, and people were employed, by maximizing the required number of operations performed, regardless of their actual impact.

Shaposhnikov, for example, has complained openly that the monopoly position of the Ministry of Aviation Industries has compelled the Air Force to purchase weapons which were not

46 Interview with Marshal Yevgeiy Shaposhnikov, "Igrat' v politiku armiya ne namerena," Literaturnaya Gazeta, No. 11, 17 March 1993, p. 11.

required and often not wanted.\footnote{Colonel A. Manukhin, "Den'gi lyubyat schet," \textit{Krasnaya Zvezda}, September 15, 1990, p. 2.} In addition, according to Shaposhnikov, newly-produced aircraft have often been "raw," not meeting pertinent requirements and standards, and certainly not responding to the requirements originally set by the military service. The most telling source of information about the "diktat" of the producers comes from a recent article by a former aircraft test pilot in the pages of the monthly Soviet air force journal.\footnote{A. Akimenkov, "Chto messhayet nashim samolyetam byt' lushche," \textit{Aviatsiya i kosmonavtika}, July 1990, pp. 18-20.} According to this commentator, from the very beginning stages of the formation of requirements for an aircraft system, the Air Force succumbs to the will of the Ministry of the Aircraft Industry, which in turn simply responds to the "diktat" of the designers and producers. Even the famed tactical-technical requirements (TTZ), which set system specifications early in the procurement process and which Western analysts previously thought were binding on the designer and producer, are, according to this author, only a secondary document. He claims that a final decision on the concept of a future aircraft is generally worked out long before the TTZ is signed, and that this concept takes into account solely the needs of the industrial producers, and only secondarily (if at all) the combat needs of the military service.
One recent analysis from Russian Federation Vice Minister of Defense Andrei Kokoshin is particularly telling. In a discussion of concerns over improving quality in weapons development, Kokoshin insists that a whole new system will have to be put in place: one in which the whole cycle of armament design will be divided into several phases, with each of those phases closed with an experimental confirmation, and the volume of investments for each subsequent phase dependent on the success and quality of implementation of the preceding stages. This discussion, of course, indicates that the Soviet Union did not have such a system in place previously, and that therefore other factors must have determined how and why weapons systems made their way through the procurement pipeline.

Indeed, there is additional evidence that designers have traditionally tried to carve out a role for themselves in setting military requirements for weapons systems. Some sources even claim that the defense sectors of industry, rather than the armed forces themselves, are the true initiators of new weapons systems. One of the most prominent aircraft designers in Soviet history, Alexander Yakovlev, has explained that Soviet designers have always understood that the designer is obligated to be a military tactician as well,

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that is, he must know well all the characteristics of his weapons systems and the most effective uses of new designs in combat conditions. This statement certainly implies that the designers have felt free to tamper with original Air Force specifications for the types of weapons systems which should respond to particular tactical challenges.  

The story that emerges is one of designers and producers being interested only in meeting their gross output requirements with the minimum required effort; because of a lack of competition between design bureaus and production associations, the customer had little alternative but to take what he is given. Occasionally competition was nominally attempted, but generally the results were not incorporated into the weapon system to be produced; the development of more complex and expensive prototypes such as aircraft was begun on a competitive basis, but then both variants were selected, and effectively analogous items were produced in parallel.  

Institutional interests often determined the results of these mock "competitions." Design offices and military plants had a maximum interest in having the system they developed get into production, and therefore the principle of "to everyone what he deserves" led to the purchase of several types of


armaments, the combat properties of which differ only insignificantly. All the designers wanted their prizes and perks; none wanted to be left out. The economic interests of defense manufacturers depended to a considerable extent on the scale of military production and the cost of military hardware, not its quality or responsiveness to customer demand; both salaries and the construction of housing, kindergartens, and dispensaries depended on the prices for arms, and therefore the enterprises had every incentive to strive for a cost-is-no-object approach to high quantity production.

Although, therefore, the Ministry of Defense remained in formal terms the procurer of the weapons, the product range, development times, and volumes of deliveries were dictated by the monopoly enterprises. As one participant phrases it, the defense industry operated according to the principle "either accept for commissioning what we can do and at the price set by us, or you will not receive anything." Of course, industry's preference remained with the simpler designs incorporating fewer technological advances, since their

53 Belous, p. 6.


55 Yurkov, September 1989, pp. 80-86.

development and production entailed less risk and therefore less chance of missing valued gross output production bonuses. The result, of course, was a serious reduction in the combat readiness and effectiveness of the entire Soviet armed forces. Large numbers of low-quality weapons were produced, their models and types completely unstandardized. For example, at one time the military installations of the Soviet armed forces employed over 400 types of engines, whose operation required 250 different types of fuels and lubricants, while the 21 different types of tracked vehicle used 17 types of engines, 20 types of tracks, 19 types of rollers, etc. Operation and maintenance of such an array of equipment was difficult, to say the least.

Another source reveals the same dynamic surrounding Soviet expenditure on ballistic missiles, claiming that unnecessary stockpiles of missiles were maintained and never fitted into launch silos. Instead, they were built to keep factory workers employed and paid bonuses, not for any specific military requirement. Additional missiles, beyond those ordered by the Ministry of Defense, were routinely delivered, just in the initiative of industry.

These weapons were primary manifestations of the "na sklad," or "for the warehouse," phenomenon, in which

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storerooms held "piles and piles" of military hardware either not ordered by the state, or ordered but not paid for because it was of unusable quality. Such plan overfulfillment was frequently rewarded even if there was no demand for the goods involved; given the unreliability of wholesale supply lines, it made sense for enterprises to maintain excess input stocks in order to ensure their ability to meet future production targets.

In addition to the monopoly problem, the military services have also had no control over these phenomena because of the way resources are distributed for defense. Andrey Kokoshin explains that the Defense Ministry leadership often was unable to influence the procurement of specific weapons systems because the money for scientific research and experimental design work was allocated directly from the Military-Industrial Commission, the Politburo, or the Central Committee defense industry department. Even into the early 1990s, only fifty percent of the allocations for scientific research work was paid to the Ministry of Defense, that is, to the organization in whose interests the work was being carried out. The remaining half was covered by the state budget,


bypassing the MoD.\(^6^1\) Apparently a similar situation governed the allocation of resources for weapons production; Shaposhnikov has argued that in order for arms production to respond effectively to the needs of the service, all money allocated for the purchase of arms must be at the disposal of the services.\(^6^2\) In other words, authority and responsibility must not be so diffuse as to become meaningless; the customer must have influence over the course of fulfillment of the order he places.

The Main Shipbuilding Directorate of the Navy, for example, is responsible only for the stages of weapons development beginning with the technical specifications for ship design and ending with its being turned over for operation. Other organizations of the Navy are responsible for the ship's operation until it is decommissioned. When, therefore, the fleet technical directorates make claims against the designers and industry for design and production flaws, the Main Shipbuilding Directorate often takes their side, trying to shift all the responsibility on the ship's operational personnel.\(^6^3\)

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\(^6^2\) Manushkin, p. 2.

For years, the armed services were frustrated into silence about shoddy weapons deliveries. If they refused to accept poorly performed work, the administrative system would simply assure them that things would be improved during the next plan cycle. The same was true with complaints about safety, efficiency, productivity, and quality. Soon, according to one observer, the user of the weapon system began to realize that he was alone in the bureaucracy, and that no amount of complaining would change the situation. "There are thus always clear skies over the contractor, neither competitors nor the risk of material losses chase him, and there is no need for him to exert himself."64

The armed service customer could take some solace, however, in the weapons designer's position vis-a-vis his subcontractors. Although the general designer of a system had to rely on other producers for component parts, control over those producers was located in their ministries. As a result, there was little penalty to them if they did not cooperate with the main contractor, as long as they fulfilled their ministries' gross output targets. As the deadline date for initiating flight testing of a new aircraft, for example, drew near, the general designer may have felt panic because all of his on-board systems had not been delivered. He had two options: he could delay the entire process until the weapon was completely ready, or he could substitute older subsystems

64 Stefashin, p. 19.
as best he could. As a rule, he chose the latter. The first flight proceeded according to the predetermined timetable, regardless of whether the system being tested remotely resembled the system that was originally ordered or the system that would eventually be fielded. Thus began the process of expensive and extensive refinement of weapons that were not properly developed on the ground, earlier in the procurement process.

One of the major consequences of this unresponsiveness to customer demand was that designs were often given final modifications during series production and actual field use of equipment rather than during the experimental design and testing phases, when those changes would have been less costly. After state testing of an aircraft, according to this source, the following was usually recorded into a formal document: "The product can be adopted into operational service after elimination of the following flaws:" or "after the following work is performed:". A long list inevitably followed; one author counted 1,000 such flaws listed in such a document for one of the fighters.\(^65\) To illustrate further, for years the following joke made the rounds of the Soviet Air Force: the CIA receives the plans for a new Soviet fighter aircraft. They begin to assemble it from those plans, but it turns out to be a tractor. They send an urgent inquiry to their agents in the field: "What did you send us?" After some

\(^{65}\) Manushkin, p. 2.
confusion, a reply is received with apologies -- the agents were unable to get the list and schematics of modifications in time.\textsuperscript{66}

Representatives of the military services now feel free to complain vigorously about the consequences of this situation they have endured for years. One Navy captain explains that as soon as a ship comes on line, the service immediately opens up an individual file for it into which all the complaint correspondence to the manufacturer is collected.\textsuperscript{67} Apparently these files fill up rather quickly, and the problems are not limited to ironing out initial "bugs" -- the same defects are duplicated year after year in series-produced models. The manufacturer simply ignores the conditions in which the ships will have to operate; for example, the antenna posts on some cruisers have inadequate water protection.\textsuperscript{68} Similarly, the artillery radar on one particular guided missile cruiser has to be adjusted and serviced by the manufacturer's representative before practically every cruise.\textsuperscript{69} In another case, during production of nuclear submarines one of the workers incorrectly installed a bearing on the shaft, which made the shaft vibrate; consequently, the gear teeth of the

\textsuperscript{66} Manushkin, p. 2.


\textsuperscript{68} Ishchenko, p. 2.

\textsuperscript{69} Ishchenko, p. 2.
pinion installed on it wore out quickly. The same defect consistently occurred on several ships.\textsuperscript{70} Perhaps most dramatically, the state commission investigating the Mike class submarine disaster found a large number of technological problems in its design. Admiral Chernavin offers the defense that the ship, the Komsomolets, was designed in the 1960’s, and therefore its equipment is not the latest. But according to two reserve submariners, the vessel is the rule, not the exception; it is impossible to imagine, they say, "an underwater cruise without a fire or a breakdown nearly every day. This is not a cruise -- it is a madhouse. This is the kind of nuclear submarines they build for us."\textsuperscript{71} Indeed, two years after the destruction of the Komsomolets, the Navy command permits some nuclear submarines to be sent to sea with exactly the same deficient flotation chamber. Should another accident occur, the seamen have no hope for escape because of the jams in the exit hatches.\textsuperscript{72}

Dreadful accidents were a primary byproduct of this system of weapons design, production, and acceptance. On


\textsuperscript{71} Cap. 1 rank A. Bystrov, "Gibel' 'Komsomol'tsa': Real'nost' i domysly," \textit{Krasnaya Zvezda}, May 13, 1989.

ships, for example, freon fire-extinguishing units were frequently activated by false alarms on destroyers, poisoning several seamen with the considerable quantities of toxic freon which entered the compartments where they were stationed.  

The cause of the injuries: the damage control sensors in the compartment were routinely not activated, and therefore the control post received no indication that the fire-extinguishing systems had been turned on. Several years of complaints about the faulty sensors to the designers and builders produced no response.

These problems were not unique to the Navy. One out of every three accidents in military aviation is due to equipment failure. According to one observer, it is "unfinished" aircraft entering service which are responsible; designers and producers count on bringing the plane up to specifications while they are in service. "Branch offices of the Minister of Aviation Industry" were opened in combat units, where brigades of several dozen personnel perform finishing work. During the period of "trial" operation, for example, the Tu-160 ("Blackjack") bomber stood idle undergoing "finishing" touches for more than eight years.

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One aircraft researcher explains that incomplete and inadequate equipment is routinely brought to the Air Force for testing.\textsuperscript{75} Hundreds of flaws, and ways in which the weapon is not up to specification, are detected, but most of these are not eliminated in the course of the test program and therefore persist through prototype development into early series production and operational service. Since cost is no object, the designers and developers are invited to perform corrections and refinements during and after flight testing, which is labor intensive, complex, inefficient, expensive, and often ineffective. Since a multitude of equipment failures occur in the meantime, the weapon system and units using it suffer frequent down times.

Since cost-effectiveness is not an issue, there is no incentive for the designer to find a more efficient testing means other than flight testing. In fact, since priority is given in the creation of the aircraft to the meeting of specific deadline dates, there is disincentive to slow down the process by making corrections during development. As a result, the physical quality and technological sophistication of the testing equipment has lagged behind that of the items being tested over the years, so that often even a rigorous testing program would not catch significant defects. It is

\textsuperscript{75} Col. A. Stefashin, Candidate of Technical Sciences and Deputy Chief of an Air Force Scientific-Research Institute, "Ten Thousand Patches, But More Rips," Aviatsiya i Kosmonavtika, No. 12, December 1990, pp. 18-19.
therefore difficult in many cases to say with certainty, even after testing, how a weapon system actually performs.\textsuperscript{76}

What happened to the designers and producers if they failed to respond to their most urgent incentives, quantity of production by a given deadline? Apparently not much; "they would have to go to the ministry or to the military-industrial commission and get the deadline changed."\textsuperscript{77} Since new quotas and deadlines routinely magically appeared, workers were not even deprived of their bonuses.

In other words, the incentives in the defense industrial sector were not different from those in the rest of the Soviet economy: everyone was guaranteed employment, earnings were guaranteed, productivity and quality incentives were absent, orders were fulfilled slowly, and because of the backlog of orders created as a result, the illusion of high workloads was created.

Most production associations do not even have institutionalized arrangements or facilities for accepting complaints.\textsuperscript{78} Indeed, the head of the Progress aircraft engine design bureau has remarked that his organization has not given much thought to defect-related engine replacements, since it knows that any such problems will be compensated by

\textsuperscript{76} Stefashin, December 1990, p. 18.

\textsuperscript{77} Stefashin, p. 19.

\textsuperscript{78} "Kritiku -- v shtyki: vosprinyali na oboronnom predpriyatii, postavlyayushchem nekachestvennyu tekhniku na korabli," Krasnaya zvezda, November 14, 1989, p. 2.
the Ministry. Similarly, according to data provided by the Main Military Procuracy, in the late 1980s and early 1990s major manufacturing defects were detected on twelve nuclear-powered submarines, 29 surface ships, and five service craft. At no time, however, have the designers or producers of these vessels offered the Navy a new design for ensuring ship survivability.

As noted above, it has generally been assumed by Western analysts that one of the filters preventing these types of phenomena was the network of "voyenpredy," or military representatives, who provide quality control in defense sector enterprises. According to one source, however, these representatives act as "more of a coarse than a fine filter." They simply don't have the personnel or technical expertise to monitor the production process in fine detail; weak areas are therefore revealed only during the testing stage.

Probably more importantly, however, military representatives are assigned not only their housing but other "extra-budgetary" privileges not by the military garrisons by whom they are technically employed, but as an appointment of

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80 Captain 1st Rank S. Turchanko, "Two Years Later," Krasnaya Zvezda, 28 August 1992, p. 3.

81 Manushkin, p. 2.
the enterprise they are assigned to oversee. Furthermore, Communist military representatives have been listed on the Party register in the factory itself. The enterprise management therefore decides whether or not these people receive an apartment and other perks based on their loyalty to the factory. Herein lies their proclivity to "overlook" irregularities they should in fact report to the service.\(^2\)

Essentially, the military representatives fall under "dual control." Their responsibility for timely deliveries of equipment, regardless of quality, is more urgent than their responsibility for quality control. A monthly account and report have to be made to the former, who does not want to hear excuses for gross output targets and deadlines unmet. The military representative apparently finds this refrain quite familiar: "I am not asking why! I am asking why the equipment was not delivered on time?!"\(^3\)

The military representatives also play a role in investigation of accidents. One designer tells of an occasion when the Soviet Air Force lost two two aircraft in Afghanistan due to a hydroelectric system failure. The Air Force blamed the aircraft design, but other investigators sent to

\(^2\) Puteyev, p. 2. See also Lt. Col. V. Zhilyakov, "The Military Representative Under Dual Control: What Forces Him to Shut His Eyes to Waste," Izvestiya, January 24, 1990, p. 2, for an account of the extraordinary harrassment afforded one military representative who tried to "blow the whistle."

Afghanistan by the design bureau found instead that the root of the problem was with local aircraft maintenance. A debate ensued, and military representatives were sent to adjudicate. They found in favor of the design bureau, motivated, in this designer's opinion, not by their objective findings, but by the fact that the design bureau provided them with their apartments and other perks.\footnote{Interviews.}

As a result, military representatives are regularly regarded as useless by their coworkers. One of them recounts:

I recall how all military representatives at the plant where I worked from 1977 through 1987 engaged regularly (3 times a week) in physical training at the plant gymnasium to fulfill an order of the Minister of Defense. We who arrived in the morning were invariably greeted by the cleaning lady with one and the same words: "Huh, the plant parasites!" And in my heart I had to admit she was right.\footnote{Khokhlov, p. 11.}

Even under these implicit threats, some military representatives occasionally attempt to perform their assigned duties rigidly. In such circumstances, enterprise directors have been known to call in the Party hierarchy, with demands for "explanations" and threats to investigate personnel matters. One anecdote from the Soviet press relates the tale of a military representative who tried to speak up about the problems at the factory where he worked.\footnote{Zhilyakov, 1990, p. 2.} A collective action suit was brought against him by the plant, the charge
being "official malfeasance." He was released from his position and demoted to the status of "ordinary worker." Several years later, this same man was accused of theft; the RSFSR Prosecutor's Office terminated the investigation for lack of evidence, and even raised the possibility of filing charges against the factory officials for initiating an unjustified criminal investigation. 87

Impact on the Military: "Diktat" of the Ministries

Not only service-industry organizational dynamics, but also within-industry relationships determined the shape of Soviet weapons systems in the procurement pipeline. Resource power plays governed the dynamics of relationships within the military industrial structure itself in a manner that inhibited innovation. 88 One of the main specifications for the Su-25, for example, was survivability, and to that end the Sukhoy design bureau proposed use of a new material never before produced in the Soviet Union for construction of the fuel tank. The Ministry of Chemical Industries, however, insisted that they continue with the old method of using neutral gases to protect the fuel supply; it took three years for the design bureau to convince the Military-Industrial

87 "A Hostile Reception for Criticism," Krasnaya Zvezda, November 14, 1989, p. 2; for an account of another similar case, see Turchenko, 1992, p. 3.

88 Data in this section are taken from interviews with Soviet aircraft designers.
Commission that the new materials were desirable and to establish their production.

The development of the Su-25's cabin armor was similar. The Sukhoy bureau discovered early in the aircraft's development process that titanium would be a more effective material than steel, but at that time the Soviet Union's entire titanium supply was allocated to submarine production. It was therefore necessary to take the time to produce prototype cabins from both steel and titanium, and to conduct exhaustive live-fire tests on both types, before the Military-Industrial Commission would allocate the titanium to the aircraft. The designers were therefore often frustrated with a system that required them to go up through the VPK's organizational hierarchy to secure new materials, instead of simply contracting with appropriate suppliers.

The MiG-29 weapons control system (WCS) was similarly critically affected by the need to satisfy ministry interests. It was divided into two separate subsystems, the RLPK radar sighting system, under the control of the Minister of Radio Industry, and the OEPRNK-29 electro-optical sighting system, under the Ministry of Aircraft Industry. This division was made not to improve performance or reliability, but to make it easier for the Central Committee to monitor who was responsible for achievements and setbacks, and therefore who would get rewards and reprimands from the Party. In fact, the separation prohibits effective communication between the two
subsystems, so that the WCS cannot realize maximum performance.\textsuperscript{89}

**Soviet Weapons Preferences: Quantity over Quality?**

The evidence therefore shows that the Soviet state, specifically its armed services, could not successfully ensure implementation of weapons specifications it demanded. These data also contradict the standard litany about Soviet military culture, which goes something like this: the Soviet military culture is thought to contrast with the American along several dimensions. From the Soviet perspective, one cannot be too strong militarily. There is no sense of recognition of the security dilemma.\textsuperscript{90} The maintenance of a large standing army is the legacy of a somewhat unstable multinational empire, surrounded by actual or potential enemies, plus the added duty of the last eighty years to prosecute the historic mission for which the USSR was founded. Sources of the belief in amply endowed forces go far back in Russian and Soviet history, including traditional self-perceptions of inferiority and bitter memories of the cost of inferiority left from the Nazi onslaught of 1941. More recently, the Cuban missile crisis

\textsuperscript{89} Comments by Alexander Velovich, former Mikoyan engineer and staff member, quoted in Halberstadt, 1992, p. 39.

taught the Soviets never again to be caught in a numerically inferior position. The Soviet Union has therefore chosen to stress numbers over technological sophistication, and has evolved a design philosophy of evolutionary development, commonality and simplicity, enabling it to extract more military value from its R&D. One of the lessons of World War II was the importance of designs that are easy and cheap to produce in mass quantities.

The Soviet emphasis on mass over quality, according to military cultural theories, also has to do with the Soviet way of thinking about war. To the Soviets, war is a science. Soviet military thinkers define military science as a unified system of knowledge about the preparation for and waging of war, and the discovery and study of objective laws of armed conflict. Intolerant of uncertainty, they try to plan and prescribe every operational maneuver, down to the last detail. Their traditional emphasis on mass, on large numbers of troops and weapons, is attributable to this fear of uncertainty. They calculate that mass can average out the differences caused by unforeseen circumstances, relying on the synergy achieved by combining technically inferior weapons in somewhat elaborate strategic schemes to offset or overcome Western technological superiority in specific weapons systems.91 This

tendency was reinforced massively during World War II, when a qualitatively superior German force was defeated with sheer Soviet numbers.92

In addition, the Soviet Union has a strong combined arms tradition. The Soviet military has been dominated by the ground forces, which is to be expected from a continental power with restricted access to the open ocean, and which in World War II fought an overwhelmingly land-oriented campaign to complete victory. Soviet long-range aviation and naval forces were overshadowed bureaucratically by the ground forces, and it is the former that generally embody the most technical sophistication. The problems of training a mass army also contribute to a conservative design philosophy, with easy-to-operate, user-oriented weapons. This procurement strategy also compensates for the limited supply of highly-skilled technicians for engineering, development, and repair.

These factors seemingly would predict a deliberate emphasis on quantity over quality in setting and carrying out design requirements for Soviet weapons. The data presented in this chapter, however, seem to indicate otherwise; the observed quantity-over-quality phenomenon has resulted from the perverse incentive structure of the Soviet economic system and weapons procurement process, not from a sense of intentionality.

92 Head, 1974.
Differing Organizational Propensities for Risk

Even within this industrial environment within which the Soviet design bureaus operated, the evidence indicates that some designers instilled in their organizations a greater propensity to "buck the system" in order to take risks relative to innovative technological development than others. The Sukhoy design bureau has historically adopted a vigorous, risk-taking approach to aircraft design, displaying a willingness to adopt new technologies into weapons systems earlier than its counterpart, Mikoyan. The Su-27, for example, incorporated from its inception fly-by-wire, an electronic flight control system that represents a radical departure from earlier hydraulic-mechanical devices; such a system did not appear in the MiG-29 until very recent upgrades. Similarly, the Sukhoy firm has aggressively explored joint venture opportunities with the West to a much greater extent than Mikoyan.

M. P. Simonov, Sukhoy's General Designer, explains that the differences stem from the way Pavel Sukhoy, the bureau's founder, initially conceived of cooperative scientific work. Sukhoy understood that successful scientific inquiry requires considerable freedom of intellectual maneuver and expression, and therefore "concocted" his collective in a spirit of considerably less formal relations between scientists and
designers than has been standard Soviet practice. He made it a point to gather around him young, talented, risk-oriented junior designers, and then to resolve conflicts among them regarding design problems in favor of the most far-reaching technological solutions. According to Simonov, this spirit, or culture, has endured to the present day. Simonov has repeatedly stressed that his mode of design operation is to push the parameters of whatever technology he is working on to the maximum possible limits, the theory being that "what today is the limits of a regime, tomorrow will become commonplace."

The Mikoyan Design Bureau, by contrast, seems to espouse a more conservative design philosophy. General Designer Rostislav Belyakov has stated that the MiG-29, as well as all other MiG's in his experience at the design bureau, was designed under the guiding principles of maximum simplicity of construction, with new technologies introduced only if they provided a noticeable qualitative growth in the potential

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95 For numerous anecdotes illustrating this point, see L. Kuz'mina, General'nyy konstruktor Pavel Sukhoy, Belorus', Minsk, 1985.

capabilities of the aircraft. Mikoyan deputy chief designers and test pilots have echoed the same sentiments. In particular, when asked why the MiG-29 did not incorporate fly-by-wire technologies until much later than the Su-27, Mikoyan chief test pilot Valeriy Menitsky and deputy general designer Mikhail Waldenberg remarked that such systems were simply not necessary -- that the MiG-29 flies quite satisfactorily with traditional control systems. As Waldenberg has said in several interviews, "the most reliable system is one that is not on the aircraft at all; such a system can never break down." Indeed, Waldenberg is proud that his aircraft exhibits performance characteristics roughly equivalent to Western systems, minus the sophisticated electronics. "You have this advanced fly-by-wire technology in your own fighters, so just try to duplicate the flight maneuvers we can do with our old hydraulic and mechanical technology! It is not only words, but the approach of the Mikoyan Design Bureau." Other Mikoyan designers seem similarly proud of their ability to design top performance aircraft from an inferior technological base; the differences between their working conditions and those in the West lead them to claim that their designers are more resourceful and creative. Former Mikoyan engineer

99 Quoted in Halberstadt, 1992, p. 29.
Alexander Velovich:

[Soviet designers] need to produce a fighter that would match its Western competitor -- with much more modest means and equipment at their disposal. Sometimes, this situation leads to intuitive design decisions made with a pencil and paper on your knees, whereas a Western company would spend hours of expensive computer simulation and hundreds of thousands of dollars to achieve results that would be practically the same.\(^{100}\)

Another former Mikoyan designer is even more blunt, arguing that the Soviets are much more attentive to and skilled in the methodology of design in general, and the mathematics of design in particular: "Soviet designers are superior because they produce superior quality products under harsh conditions. We must do everything ourselves. This is particularly true for airframe design. [The United States] compensates for bad aircraft design with good electronics; we compensate for poor electronics with good airframes. This requires quite an innovative manner. We design good aircraft, and then tack on electronics to do more."\(^{101}\) This particular designer, in fact, regards the World War II era as the "good old days" of aircraft design. Back then, he says, the electronics did not exist to interfere with the purity of seat-of-the-pants aerodynamic engineering.

Other observers of Mikoyan indicate that the differences may not necessarily be of entire design bureaus, but of

\(^{100}\) Velovich, interviewed in Halberstadt, 1992, p. 43.

\(^{101}\) Interviews. For more on the MiG-29's low-tech design, see Oleg Terebov and Aleksandr Grinkin, "Samolet po imeni 'Rita' v gostyakh...i doma," Krylya Rodiny, No. 6, 1992, pp. 13, 15.
influential individuals within design bureaus. One ex-Mikoyan designer, for example, claims that the MiG-29 lacks fly-by-wire capability because the head of the hydraulic/controls department was an older, influential man who was quite clever and experienced in engineering mechanical systems; he was therefore able to dissuade the chief designer from introducing fly-by-wire. On the other hand, this observer claims, the MiG-29's infrared-search-and-track (IRST) weapons control system is much more sophisticated than the Su-27's, and this is largely due to the department head responsible for its development. In other words, much depends on the individuals holding specific responsibilities, their orientations, and their clout. Overall, however, even this ex-Mikoyan designer generalizes that Rostislav Belyakov, the Chief Designer at Mikoyan, is less likely to take risks with advanced technologies than are Samoylovich and Simonov at Sukhoy.

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Chapter Seven:
Whither the Soviet Threat, Part II:
Russian Defense Industry After the Cold War

In the current period, more specifically since 1985 when Gorbachev and his political allies began to redefine the meaning of national security in the Soviet context, domestic factors have assumed a greater role in this first stage of the procurement process. Most directly, the financial resources are simply not there as they may have been previously to support continued response to every Western threat. Indeed, some Western analysts have interpreted the now-familiar push for qualitative improvements in Soviet weapons systems as a mere euphemism for reduced quantities; the promise of qualitative improvements was simply a palatable way for Soviet political leaders to demand that the military make better use of the dramatically declining resources that would be available.¹

The situation in the Soviet/Russian defense industry has been bleak over the last few years. The patterns of expenditure within the military budget have, since the late 1980s, increasingly favored current operations and neglected research and procurement.

Table 7.1:
Soviet/Russian Military Budget Categories
(by percentage of total military budget)\(^2\)

<table>
<thead>
<tr>
<th>Category</th>
<th>1990</th>
<th>1991</th>
<th>1992</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personnel maintenance</td>
<td>27.2</td>
<td>33.4</td>
<td>54.7</td>
</tr>
<tr>
<td>Payments for hardware</td>
<td>43.7</td>
<td>37.3</td>
<td>16.1</td>
</tr>
<tr>
<td>Research &amp; development</td>
<td>18.6</td>
<td>16.7</td>
<td>10.6</td>
</tr>
</tbody>
</table>

As a result, production output has fallen dramatically:

Table 7.2:
Soviet Military Hardware Output, 1989-1991\(^3\)

<table>
<thead>
<tr>
<th>Category</th>
<th>1989</th>
<th>1990</th>
<th>1991</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main battle tanks</td>
<td>1700</td>
<td>1300</td>
<td>1000</td>
</tr>
<tr>
<td>Infantry fighting</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>vehicles and APCs</td>
<td>4800</td>
<td>3600</td>
<td>2100</td>
</tr>
<tr>
<td>Artillery pieces</td>
<td>2500</td>
<td>1900</td>
<td>1000</td>
</tr>
<tr>
<td>Bombers</td>
<td>40</td>
<td>35</td>
<td>30</td>
</tr>
<tr>
<td>Fighters and fighter-bombers</td>
<td>650</td>
<td>575</td>
<td>350</td>
</tr>
<tr>
<td>Attack helicopters</td>
<td>100</td>
<td>70</td>
<td>15</td>
</tr>
<tr>
<td>Submarines and major</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>surface combatants</td>
<td>21</td>
<td>20</td>
<td>13</td>
</tr>
<tr>
<td>Strategic ballistic</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>missiles</td>
<td>200</td>
<td>190</td>
<td>145</td>
</tr>
</tbody>
</table>

The Mikoyan Design Bureau's Chief Designer Rostislav Belyakov explains that, as a result of these cuts in government funding for military research and design, his


institute is operating on a "starvation diet." He claims that, through early 1993, his design bureau is actually allotted sufficient government funding to conduct necessary experimental design work, but that 60 percent of that returns to the state budget in the form of taxes. Other aircraft industry officials complain that what little money is allocated to them often does not arrive on schedule. "Money we need in the first quarter will arrive in the second." A January 1993 decree of the Supreme Soviet of the Russian Federation specified that, in order to account for inflation, the Ministry of Defense was to be allocated funds for arms design and production on a monthly basis, and that 40 percent of the total annual budget was to be paid out in the first quarter. As of March 1993, however, the Ministry of Defense did not have the necessary resources to settle its obligations to defense industry not only for the first quarter of 1993, but for much of 1992. Inflation is a major problem for the

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5 See also Belyakov's comments in "Kosilki... grusherezki...ili vse-taki -- MIGi," Krasnaya Zvezda, 6 February 1993, p. 3.

6 Vladimir Ivanov, president of the Russian aviation lobby group Aviaprom and former aviation minister, quoted in Douglas Barrie, "Russian Roulette," Flight International, 2-8 June 1993, pp. 23-24. Other sources stress that government funding arrives not only late, but not in the amounts promised. Interviews.

defense research and design organizations. The Central Aero-
and HydroDynamics Institute (TsAGI), for example, received at
the beginning of 1992 what on paper looked like a 100% funding
allocation for the year. Even with government adjustments,
however, by the end of the year that money amounted to less
than half of the institute’s needs.8 One source explains that
the military research and development facility personnel have
not yet developed the necessary financial and business skills
to protect what scarce resources they do have from inflation.
They remain largely mystified by their new economic
environment.9

As a result, research facilities and design bureaus have
been forced to look elsewhere to fund their defense programs.
The Mikoyan design bureau, for example, financed its
development efforts for at least six months in 1992-1993 using
about $400,000 it cleared from selling rides in MiG-29s at
American air shows in the summer of 1992. Without this money,
the design bureau would have been forced to shut down at the
end of that year.10 Mikoyan’s current operating budget is
30%, in real terms, of what it was during the Soviet period.

In general, the Russian military design bureaus are receiving

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8 Interview with German I. Zagaynov, TsAGI Director, by Craig
Covault, "Yeltsin To Review Russian Aerospace Plea," Aviation Week
and Space Technology, 24 May 1993, pp. 22-23.

9 Interviews.

10 Interviews; and David R. Markov, "The Radical Reshaping of
between 25 and 30 percent of their former government research and development funding.\textsuperscript{11}

Because of the lack of resources, the design bureaus are churning out far more designs on paper -- "solutions in search of problems" -- that viable aircraft programs that will ever have a chance of entering full-scale development.\textsuperscript{12} The following chart reveals the extent to which many of the Soviet/Russian aircraft programs rumored in the West to have existed for quite a few years have in fact never made it off the drawing board due to lack of government interest and funding. If and when new systems do begin to emerge off the design table and into the pipeline, it is clear that the Air Force intends to rectify what it now sees as the inefficiency of stocking its inventory primarily with single-role aircraft. Officials at the highest level of the Soviet/Russian armed forces have stated that the Air Force will both reduce the numbers of types of aircraft in its inventory, and accelerate the conversion of operational units to multi-role systems.\textsuperscript{13} Some Soviet designers have claimed that this trend is a response to the constraints put on sheer numbers by recent

\textsuperscript{11} Interviews.

\textsuperscript{12} Interviews; see also Craig Covault and Boris Rybak, "Russia Revamping Aerospace Identity," \textit{Aviation Week and Space Technology}, 7 June 1993, pp. 58, 61.

Table 7.3: Recent Russian Tactical Aircraft Programs

I. Mikoyan Design Bureau

**MiG-29K**
Mission: Naval variant of MiG-29.
Status: Lost competition to enter service against Su-27K.

**MiG-29M**
Characteristics: Radical upgrade of MiG-29. New weapons control system, with improved air-to-air capability and a five-fold increase in air-to-ground capability. Eight weapons stores points (as opposed to six on MiG-29). Narrow-beam synthetic aperture radar provides excellent air-to-ground mapping. Heavy use of welded aluminum-lithium structure that saves weight and space without sacrificing strength.
Mission: Full air-to-air and air-to-ground capability.

**MiG-29S**
Characteristics: Variant of MiG-29, similar to MiG-33. Compared to MiG-29, longer fuselage, larger wing area, modified wing leading edge, upgraded RD-33 power plants. Mechanical flight control system.
Mission: Multi-role, but optimized for air-to-air.
Status: Unclear.

**MiG-33**
Characteristics: Deeper modernization of MiG-29 than MiG-29M or MiG-29S. New radar, new infrared search and track system, more powerful engine, fly-by-wire flight control system. Capable of higher angles of attack than MiG-29 through vortex generators on wing leading edges.
Mission: Multi-role.
Status: In flight test since July 1992. Mikoyan officials claim will eventually equip Russian Air Force, but funding sources uncertain.

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Project 1.42
Also known as: "ATF-ski," MFI (multi-role fighter), CAF (counter-air fighter)
Status: First flight planned for 1991, but still hasn't flown. Zero funding from Russian Air Force. Prototype exists, but appears destined to become "hangar queen." Mikoyan would like to see enter service shortly after 2000. If ever makes it into production, may be designated MiG-35.

Project 7.01
Also known as: MDP (long-range multi-role fighter), ASF (air superiority fighter)
Characteristics: Derivative of MiG-31 Foxhound.
Mission: Long-range, multi-role fighter.
Status: Lacks funding. Still on drawing board.

II. Sukhoi Design Bureau

Su-27K
Mission: Naval variant of Su-27.
Status: Won competition with MiG-29K. In production.

Su-271B
Mission: Two-seat strike variant of Su-27.
Status: Slow funding from Ministry of Defense. One aircraft in flight test, two in final assembly to be placed in flight test.

Su-35
Mission: Primarily air-to-air, but with air-to-ground capability.
Status: Several flying prototypes exist, each associated with different aspect of the program. Flew briefly, ten-minute routine, in September 1993 at Moscow Air Show. Has production funding from Air Force; Sukhoi anticipates first production aircraft will be delivered in late 1995.
Su-30MK
Mission: Been proposed to Russian Air Force as medium bomber to replace Su-24.
Status: Unclear. Su-24 service life still substantial, and therefore unlikely that Su-30MK will receive Air Force funding for quite a while.

Su-37
Mission: Single-seat, multi-role, optimized for air-to-ground. Deep and tactical strike, reconnaissance and interception in all weather, 24-hour conditions. Not a response to a threat, but intended to compete with F-22 on international arms markets.
Status: In development. Scale model shown at November 1991 Dubai Air Show. No Air Force funding yet; only in wind-tunnel tests on scale models. Sukhoi searching for foreign partner for project.

T-60
Characteristics: Replace Tu-16 Badger, Su-24 Fencer, Tu-22 Backfire.
Status: Won stiff 1992 competition with Tupolev. Well-developed design work, but development and production not approved or funded.

F-22 type fighter
Characteristics: Stealth.
Mission: Compete with Mikoyan Project 1.42 to replace Su-27.
Status: Government funding for R&D only.
conventional arms control agreements, but an equally plausible explanation is that the resources simply no longer exist to produce aircraft in their former quantity.

**Threat Assessment?**

In such an environment, it seems reasonable to ask whether serious threat assessment is driving Soviet/Russian weapons, specifically aircraft, requirement calculations to the extent it did in the past. Some of the recent threat assessment literature clearly attempts to downplay the significance of Western stealth technology. One major Soviet account of the combat use of the F-117 in the Persian Gulf suggests that, while quite effective in some circumstances, the aircraft was not completely invulnerable to modern radar equipment. In particular, the Soviet author notes, the French-made "shakhinya" radar deployed in Saudi Arabia detected the stealth fighters on several occasions at a range of 20 km or more when the aircraft flew at an altitude of 2-3 km at a speed of 900-1,000 km/hour. Another similar Soviet analysis concludes that the problem of detecting stealth weapons is not as intractable as previously thought. It cites the use of super-wideband radar, combining radars into a network that includes real-time correlation data processing,

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15 Interviews.

application of non-linear radar effects, and other technical solutions to defeat low-observable Western systems. It could be that these relaxed assessments of the threat emanating from Western stealth technology are rationalizations; if the Soviet/Russian defense industry complex is not capable of responding to a threat, then the logical course of action might be to downplay that threat's urgency. In fact, Russian fighter pilots interviewed at their bases in late 1991 indicated that they were not concerned with the threat from the West, but instead about the possibility that they might have to engage forces from the breakaway republics which have since become independent states.

Regardless of specific threat assessments contained in individual articles in the Soviet/Russian military press, it is clear that, for at least a few years in the late 1980s and early 1990s, very little was happening in terms of real formation of doctrine from which weapons designers and producers could draw guidance. First Deputy Defense Minister Andrey Kokoshin, for example, has been quite explicit in lamenting the lack of a military doctrine and an ensuing concept for development of the armed forces which might have guided orders for military hardware. "But we have yet to


arrive at this logical and entirely correct position."\textsuperscript{19}

Weapons designers similarly comment on the lack of guidance for their actions. Yu. Koltsov of the Yakovlev aircraft design bureau explains that his country has no clear system for filtering, evaluating, and analyzing the concepts of development of armaments programs. When asked, for example, why the Air Force had shown no interest in the Yak-141, he replied that no one had actually thought seriously about the question. No organization had conducted any sort of investigation into the expediency of using VTOL in the Air Force. "I hate to say this, but I do not think that we have a working military doctrine. We are really just groping our way along."\textsuperscript{20}

The new Russian military doctrine finally approved in November 1993 calls for focusing resources on new weapons technologies and materials in order to rapidly build new generations of weapons. In fact, Vice Premier Oleg Soskovets, in charge of the defense industry sector, told a meeting of directors of leading defense industrial enterprises in St. Petersburg on 15 November 1993 that 1994 defense equipment orders would include a large number of new types of weapons systems "to preserve the industry's high scientific and


technological potential". Along these same lines, Kokoshin has explicitly targeted the aviation and space sectors as "locomotives" of Russian national industry, and therefore as worthy recipients of any sort of assistance they need not only to survive today but to accumulate completed work for the future.

It is unclear, however, that the defense research and development establishment has the wherewithal to implement this concept. Russian aircraft industry sources speaking more informally explain that the armed services' priorities for several years have been their personnel, more explicitly, the need to provide housing and better living conditions for officers, enlisted men, and their families. These sources explain that the West should therefore not expect to see new weapons systems development in response to any new doctrinal formulations; the Russian military certainly holds no such expectations, being aware of the current circumstances of the defense research, design, and production institutes. Specifically in terms of the Russian Air Force, the situation is not even urgent, since the service is comfortable that its current numbers and quality of hardware are more than adequate

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to sustain it through the rest of the century.  

The State of Russian Defense/Aviation Industry

As a result of dramatic resource cuts, the defense enterprises are barely surviving. One mid-1992 report indicated that more than 90% of the defense production enterprises in the Moscow area were completely bankrupt.  

As a result, many of these facilities have moved to shortened work weeks, and some have closed down altogether for periods of one to three months. According to the Moscow trade union federation information center, a "prestrike situation" has arisen in the Moscow defense complex. Three of the nine major combat aircraft manufacturing plants in the Soviet Union closed during 1991. By the end of 1992, 21 major defense production enterprises had closed their doors permanently, 130 more were on the brink of closure, and an additional 400 were working shortened weeks.

The funding cuts are exacerbated by increases in operating costs. Rising prices for the major commodities used

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23 Interviews.


in the aviation industry, including gasoline, whose price rose 100-fold in mid-1993, have put a brake on research, flight testing, and operations. TsAGI, for example, needs huge amounts of electricity to operate its wind tunnels; that energy, 3 kopecks per kilowatt during the Soviet period, now costs 1.78 rubles per kilowatt.\(^{28}\)

In order to continue to pay out salaries, many facilities have gone into massive debt. As of mid-1992, production enterprises alone had accumulated bank loans totalling around four billion rubles to pay wages, and more than 16 billion rubles to pay for materials and assembly parts. Total defaults on loans due in the defense industrial sector at that time amounted to 700 billion rubles for Russia as a whole.\(^{29}\) Enterprises are also heavily in debt to each other; major industrial concerns now laughably owe one another non-existent rubles in the hundreds of billions.\(^{30}\) The inflationary pressures of this activity are obvious.

Defense enterprises have also cut back on what are now considered non-essential activities. For example, there is very little testing work being performed on Russian weapons

\(^{28}\) Markov, August 1993, p. 63.


systems in development; when corners have to be cut, extensive tests are one of the first things to go. One account put the Air Force 40 million rubles short at the end of 1991 to complete tests on "next generation aircraft." The research institutes are suffering from this method of cutting corners. G. K. Vedeshkin, the Deputy Director of the Central Institute for Aviation Motors (TsIAM), claims that tens of millions of rubles are being wasted because testing and other research procedures are being skipped; as a result, defects are passing through the procurement pipeline that could have been detected earlier. Vedeshkin warns that if the current state of affairs continues, his and similar institutes will disappear.

German I. Zagainov, TsAGI director, concurs. Military work at his research institute, which formerly constituted 50% of his business, now stands at less than 10 percent. Currently the company relies on contract work from the aircraft design bureaus, but they have no money. "They are always indebted to us because they work on credit themselves. All the design bureaus are debtors." The same is true of the Central Institute of Aviation Motors (CIAM); the testing


of military engines has been reduced along with defense budget cutbacks, and individual engine design bureaus are trying to limit the amount of test time they accumulate at CIAM facilities in order to tighten spending.\footnote{Jeffrey M. Lenorovitz, "CIAM Seeking Foreign Financing For Privatization, Test Center Upgrades," \textit{Aviation Week and Space Technology}, 20 April 1992, p. 50.}

Having read the handwriting on the wall, 300,000 defense workers left their jobs in 1991, and that figure rose to 1.5 million in 1992. Between 15 and 20 percent of the top-level researchers in the defense complex have left the industry.\footnote{Maley, March 1993.} Mikoyan's Belyakov explains that his workers are paid much less than workers at civilian aircraft series production plants, and qualified engineers can leave the aircraft sector altogether and join the new business sector of the economy, earning an up to eight-fold increase in salary. From the beginning of 1991 through February of 1993, 1,500 specialists left Mikoyan.\footnote{Belyakov, quoted in \textit{Krasnaya Zvezda}, 6 February 1993, p. 3. See also Belyakov's remarks in "Lack of Funds Holds Up Mikoyan's F-22 Rival," \textit{Flight International}, 10-16 March 1993, p. 5.} As one deputy director of a major Russian military hardware manufacturer put it, "the life blood is flowing out of what had been the core of our industry. How can anyone expect our young, talented people to stay at design bureaus such as Mikoyan with an average pay equivalent of $20-
30 per month?" Other employment opportunities offer defense specialists not only more money, but new managerial challenges and more freedom in their work. In order to retain personnel and even approach keeping up with inflation, TsAGI had to increase salaries six times from mid-1992 to mid-1993; to keep senior managers, the company doubled their salaries at the end of 1992 and gave them title to their formerly state-owned apartments.38

The funding and personnel situations are not as pronounced in the production facilities, where some products can still be sold and revenue realized. It is the design bureaus and research institutes, whose products are not as immediately marketable, who are suffering. Even in these organizations, the personnel shifts have thus far been voluntary -- no one has yet been involuntarily laid off, although informed observers think this may soon happen. The average experimental design bureau, for example, had between 8,000 and 10,000 employees during the Soviet period. It is now down to 5,000 – 8,000, and most managers would like to see this number reduced quite a bit further.39

Most of the statistics involve young people going into business for themselves, often in fields having little to do


38 Markov, August 1993, p. 63.

39 Interviews.
with their former specialty. A former flight engineer for the Flight Testing Institute (LII), for example, is now the very wealthy head of a private insurance company; a former TsAGI employee, now also in the insurance business, is doing well enough to have recently purchased four Su-27s, at a price tag of around $50 million, so that a former Sukhoy chief test pilot could take an aerobatic team on a tour of the United States.  

Russian Weapons Design and Procurement in the Post-Cold War Period

After the Cold War, the course of Soviet/Russian weapons design and procurement, and in particular the dynamics of technical innovation, seem to be even more dominated by domestic factors than before. New regulations on defense industry self-financing and conversion to civilian production in the late 1980s began the reduction of the Soviet defense industrial base to a shambles. Again, because of central political control of resource distribution, the Ministry of Defense and military industries have no alternative but to be content with their new situation. In terms of the goal-oriented models of organization theory, the central government is finally taking dramatic steps to bring organizational subgoals in line with overall goals of efficiency, productivity, and innovativeness. The defense sector has

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simply not yet adjusted to the implications of this subgoal realignment. The defense sector's ability to respond to perceived threats or any other signals from the international environment has been dramatically overcome by its scramble to stay afloat in the current economic crisis, during which it has been a primary target of budget cuts and sometimes ill-conceived reform. Most of the defense industrial organizations have adopted a variety of survival strategies, ranging from attempts to find new markets and funding sources under market conditions, to exploiting the personal and political connections of their most prominent personnel.

Conversion. The course of defense industry conversion to this point, for example, has been quite haphazard. Military orders have been decreased suddenly and without warning, and defense enterprises have been left on their own to find the means to produce civilian goods to fill the gap and maintain their wage funds to pay their workers. Many state defense orders have been cancelled or dramatically reduced with only three to six months' notice. In the absence of a functioning market, the defense enterprises have had difficulty deciding what to do next. They are in many cases acting blindly, able only to guess what level of their former

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41 Interviews with Russian civilian academics working on military and military-economic issues.

defense orders will remain in the next state budget; they are often grasping at the first available type of civilian production to replace their military orders in order to maintain their wage funds.

The first reaction of many defense enterprises to the conversion effort was simply to ignore it. According to one report, the Ministry of Aviation Industries flatly refused to accept the 1990 state order for 600,000 washing machines, 70,000 refrigerators, 300,000 vacuum cleaners, and 90,000 engine units. As one aircraft designer stated, "You must understand that we are specialists with the highest skills, and we cannot waste our energies on such things. All our lives we have made and we must make aircraft." Some defense officials tried to defend their turf with the suggestion that, rather than developing an indigenous civilian production capability, Soviet weaponry should be exported for hard currency which can then be used to import consumer goods.

Mikoyan currently has about fifteen civilian aircraft

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design projects underway, including a supersonic business aircraft, a light cargo aircraft, agricultural aircraft, an aviation medical complex, and a multi-purpose air-cushion vehicle. They are finding it difficult, however, to sell civil aircraft, since Aeroflot is currently unprofitable and cutting back its fleet, and commercial structures are unwilling to make long-term loans. The design bureau has no idea how it will finance the years from design to series production of these aircraft, making it unlikely that most of the products will ever get to the market. The production facilities formerly affiliated with the Mikoyan design bureau are faring somewhat better; the MAPO Dementiev, where the MiG-29 was primarily produced, has now almost completely converted to production of the Il-114 civilian turboprop aircraft.

Sukhoy's civilian projects stress supersonic technology development, including a proposed Su-50 90-ton, four-engine supersonic transport with a 50-passenger capacity. This aircraft looks nearly identical to the Russian Air Force/Sukhoy T-100 Mach 3 cruise missile carrier aircraft that made twelve flights before being grounded by SALT Treaty provisions in the early 1970s. Sukhoy is hoping for financing for this and other projects from foreign partners. The Sukhoy

47 Interview with Mikoyan Chief Designer Rostislav Belyakov, Krasnaya Zvezda, 6 February 1993, p. 3.
49 Interviews.
bureau is also engaged in environmental and noise-related technology research, using a Su-27 equipped with a large prototype SST engine nozzle section on one engine to gather noise data; an Su-80 190-seat turboprop that designers claim could fly by 1994-1995 is in advanced development. Sukhoy and Yakovlev are fortunate to have a history of design and production of civilian aircraft even during the Soviet period; they have more experience with dual-use technologies. Even this civilian business, however, is unpredictable. Some of the new commercial investment groups have provided non-state funds to the civilian aircraft industry in Russia, but not with much enthusiasm, and certainly not if they suspect that the funding might be diverted to support military projects.

Some defense industry personnel also worry about the military surge capacity implications of conversion. If a production plant converts, they argue, it can be re-geared back to military output in a time of crisis. If a design bureau, however, stops developing new combat aircraft, then future military establishments may find themselves with no modern aviation at all. Mikoyan’s Chief Designer made the following historical argument: "If our design bureau had not had the MiG-3 fighter in reserve ahead of time, could industry have produced up to 30 of them a day during the Great

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51 Interviews.
Patriotic War?" Of course, this is a blatant plea to shift currently scarce resources away from the production facilities and to the design bureaus instead.

In 1992 alone, the Russian government allocated 41 billion rubles for conversion, scheduled to be followed by 100-260 billion in 1993, but most observers considered this to be a small fraction of what was required. One Russian official complains that, even though in 1992 the government approved, on a competitive basis, allocated credit for 853 enterprises' conversion projects, that credit was not actually disbursed. Instead of being distributed by the state Central Bank, it instead ended up in the hands of commercial banks. Those for-profit banks held the money for a substantial period of time before sending it to its destination, letting interest accumulate for their own benefit, and when they did issue the funds, they did so at astronomical interest rates.

According to Mikhail Maley, Russian State Counselor for conversion issues, Russia has tried two different approaches to conversion. The first, "physical" conversion, enacted from 1988-1991, entailed keeping 30% of existing defense-oriented

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52 Interview with Belyakov, 6 February 1993, p. 3.


firms in military production, and converting the rest to civilian production. The first positive results of this approach were expected after 2-3 years, and conversion was to be complete within 5-6 years.\textsuperscript{55} This approach and timetable required extremely large up-front investments, particularly into those enterprises which were to stop military production completely. These investments were not forthcoming, and therefore the physical conversion approach failed. It also failed because of a lack of clearly identifiable civilian programs, faulty setting of priorities, and in general the absence of clear direction as to the best use of converted industrial potential.

As of 1991, an alternate approach -- "economic" conversion -- was adopted. This approach focuses on using the international arms trade as a source of money, to be subsequently used to finance the conversion of defense enterprises not producing for export. This approach fits in with President Yeltsin's recent rhetoric, such as a November 1993 promise that conversion of military industry will not be permitted to further undermine the country's industrial capacity. Speaking to a conference of regional government leaders in Tula, he said, "Conversion must not run counter to the interests of the country's defense capability.\textsuperscript{56}

\textsuperscript{55} Mikhail Maley, "Conversion of Defence Industry Changes Concept," \textit{Military Technology}, March 1993, pp. 54-55.

Many Russian defense enterprise representatives and government officials argue that their only current choice is to turn to arms exports to earn revenue to keep their businesses alive. The Sukhoy design bureau, for example, views the Su-27's export potential as a "life saver"; the bureau sells the aircraft for hard currency and in barter arrangements. As one Russia official put it, "It is unethical to watch our own people go hungry and do nothing about it."57

One major sticking point in the area of arms exports is the issue of organizational and administrative control over the terms of sale and distribution of revenues earned. One Su-27 manufacturing plant director claims that "the state itself is robbing us." He claims to have orders for dozens of his factory's aircraft which would generate as much as two billion dollars, but his enterprise and workers would see little of that money after the tax bite is taken from it.58 Sukhoy's Simonov explains that, when his bureau first started foreign trade activities in 1988, it kept its revenues in Singapore to shelter it from customs duties and Soviet taxation. Gorbachev, however, forced Simonov to transfer the money back to the Soviet foreign exchange bank; shortly thereafter, Simonov claims, the money was embezzled from

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Sukhoi's account by greedy Soviet officials. "In the West," Simonov commented, "you put bankers behind bars for this." 59

Many different organizations have been vying for the right to negotiate aircraft sales, including the former Ministry of Foreign Trade, military departments, and producing and designing firms. The past several years have witnessed endless accusations among these parties of dumping, incompetence, and backstabbing. In particular, designers and producers of weapons systems have bickered over the right to sell their products. Simonov argues vigorously that the developer and producer must sell the output together. 60 There has, however, been some joint activity between the design bureaus and production facilities intended to wrest authority for arms sales away from the government. The major design bureaus in late 1992 formed a joint stock company called the Russian Aviation Trade House, with offices in Switzerland and Moscow. 61 Headed by Russian Deputy Aviation Minister Vladimir Laptev, the company's international arm is managed by a Western businessman who advises developing countries on financial issues. In addition, the Moscow Aircraft Production Association (MAPO) has been given the authority to deal


60 Interview with Simonov, 17 December 1992, p. 6.

directly with foreign customers, although only Oboronexport can sign final contracts. MAPO has continued, however, to lobby the government and the parliament for expanded rights in this area.\textsuperscript{62} The Supreme Council of the Russian Federation issued a draft directive on 4 June 1992 permitting the Dementiev Moscow Aircraft Production Association, one of the two batch production enterprises that built the MiG-29, to market its product independently. Dementiev had halted production of the MiG-29 for the Russian Air Force and has converted to commercial production, but the facility has more than 100 undelivered MiGs, worth an estimated $2 billion, sitting idle under the snow.\textsuperscript{63} Mikoyan Chief Designer Belyakov estimates that the money earned by his design bureau from the sale of just two MiG-29s would be enough both to implement its conversion program and develop new models of combat equipment for up to a year.

In terms of actual export deals, the major inhibiting factor is the possible lack of after-sales logistical support and availability of spare parts, which will deter serious customers who intend to keep the aircraft in service for 20-25 years. Russia has tried to counter this reluctance by marketing its wares together with complete training and

\textsuperscript{62} Interview with MAPO Foreign Economic Ties Administration Chief Fedor M. Timofeyev, by Major E. Fedoseyev, "MIGi mozhno kupit' pryamo na zavode?" \textit{Krasnaya Zvezda}, 4 June 1992, p. 3.

\textsuperscript{63} "Russia May Allow Weapon Makers To Export Products Independently," \textit{Aviation Week and Space Technology}, 15 June 1992, p. 34; and interview with Belyakov, 6 February 1993, p. 3.
maintenance packages. The T-80U main battle tank, for example, is currently offered with complete test rigs for all key components of the vehicle, to train troops not only how to maintain the equipment but also how to locate and repair a fault. Test rigs are available for the loading mechanism, powerplants, complete running gear, power supply system, driver's compartment, and complete tank mock-ups comprising the turret and hull.64

Although the implications of Russian arms sales for U.S.-Russia relations are not positive, even the most reform-minded Russian officials seem to be swayed primarily by their bank balances. Yegor Gaidar, for example, has explained, "We are not going to stoke conflicts by supplying arms to hot spots, but there are no reasons to abandon this important market."65 In fact, Gaidar has criticized the old Soviet policy of supplying arms for political or ideological reasons to allies who had neither the means nor the intent to pay for them. "Now we are selling arms not to hopeless debtors, but for hard currency or hard-currency goods essential to the country."66 Yeltsin has also explicitly motivated arms producers to make exportable goods. In a mid-1992 trip through his political

64 Christopher F. Foss, "Cut Price Weapons Challenge," Jane's Defence Weekly, 3 April 1993, pp. 12-13. Foss' article contains an extensive price list for Russian ground forces equipment currently on the international market.


66 Quoted in Enginsoy, 7-15 December 1992, p. 44.
base of Sverdlovsk, Yeltsin told the workers at the Urals railway car plant, "Sell tanks overseas, and we will leave you 80% of the foreign exchange." 67 Mikhail Maley has said that those enterprises whose facilities can successfully offer items for export will be granted special facilities and privileges. This is not only because of a critical shortage of hard currency, but also because export demand is more stable. It can be analyzed and forecasted, whereas, given the current Russian political situation, internal demand cannot. 68 More recently, Yeltsin has offered the Russian defense industry more control over both export activity and the money it yields. Yeltsin told a group of factory administrators in November 1993, "One of the central tasks is to gain a firm footing on the world arms markets. The defense enterprises should have resources to fund their own development and conversion. For this purpose, the procedure of sharing the hard currency receipts must be reviewed." 69 Sukhoy designer Samoylovich offers similar sentiments: "We can't make instant conversion -- it costs a lot, and we have to find the money ourselves. That's why we must be allowed to export arms." 70

Mikhail Maley explains, "Russia certainly doesn't need to


68 Maley, March 1993, p. 54.

69 Quoted in Sneider, 22-28 November 1993, p. 18.

70 Quoted in Lenorovitz and Rybak, 27 September 1993, p. 54.
apply for permission from U.S. or European countries to enter this particular trade, and will engage in normal international competition with them. Maley and other Russian officials sense that the United States' diplomatic hostility toward Russian arms exports is motivated by economic rather than security considerations; they cite U.S. President George Bush's willingness to promote U.S. arms sales rather heavily. In particular, some Russian officials recently have accused the United States of shutting the out of the Persian Gulf arms market; the Middle East region once accounted for 80% of Soviet arms transfers. Vladimir Laptev, head of the Russian delegation at the 1993 Dubai air show, claims that American pressure on its allies in the Gulf has blocked Russian attempts to sell aircraft in the region.

Maley has estimated the potential Russian defense export market at around $4 billion for conventional systems, with the potential to escalate to $12 billion if they target for export some of their most technologically advanced systems. Profits from these sales are estimated at between 200 and 800 percent, depending on the specific items. The Russian TOR surface-to-surface missile system, for example, which Maley claims passed

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recent firing trials with flying colors, cost less than 4.2 million rubles to the Ministry of Defense, but could sell on the world market for $15 million. Maley stresses that Russia will not try to sell products that are not competitive in the global market, but that he sees nothing wrong with dumping; he specifically mentions the possibility of sales at a price 15% below the average market.\textsuperscript{73} As far as production and quality standards are concerned, Maley claims that, although Russian products may not appear on the surface to be as "finished" as some Western equipment, they are certainly the equals of their potential competitors in terms of operational profile and reliability.

Other perhaps more objective observers claim that the poor performance of Soviet weapon systems in the Gulf War has dissuaded potential customers. The Iraqi Army used a wide range of Soviet weapons, including the T-72 main battle tank, 122 mm 2S1 and 152 mm 2S3 self-propelled artillery systems, armored command and reconnaissance vehicles, anti-tank guided weapons, and a wide range of towed artillery weapons, air defense systems (both gun and missile), and associated radars and electronic systems. Most of these systems were export versions, however, often built to a much lower standard than that in use in the Soviet army (and presumably that which is now on the market). Iraq's version of the T-72, for example, did not have the same armor package or the latest fire

\textsuperscript{73} Maley, March 1993, p. 54.
control, night vision, and ammunition deployed by the Soviets.\textsuperscript{74}

Western analysts also claim deficiencies in the Russian aircraft offered for export. While Russian fighters are aerodynamically capable and extremely inexpensive, their airframes do not last as long as Western models, their engine life is considerably shorter, and they face serious support problems.\textsuperscript{75} Offset requirements present an additional obstacle to Russian penetration of the Gulf arms market. Saudi Arabia and the United Arab Emirates, for example, both have stringent offset requirements for investment in their countries in return for buying foreign defense products. Neither Russian companies or the Russian government are in a position to close that kind of deal.

One recent innovative solution to a variety of economic problems was recently worked out between Russia and several Eastern European governments. To help retire Russian debt, the Slovak government signed a contract in October 1993 to take delivery of five MiG-29s. Hungary concluded a similar deal involving twenty MiG-29s and an air defense missile and radar system.\textsuperscript{76}

Russia has also teamed recently with two American firms

\textsuperscript{74} Foss, pp. 12-13.

\textsuperscript{75} Finnegan, 15-21 November 1993, p. 29.

to offer the Advanced Adversary Training System (ADATS), a realistic combat training course using MiG-29s and Su-27s as aggressor aircraft. According to Michael Crosby, director of international programs for GreyStone Technology Inc., the primary U.S. partner, "We bring in a turnkey system, providing the aircraft, maintenance/support, a complete academic syllabus taught at the curriculum level of an air force/navy fighter weapons school, and an operational analysis capability to analyze the response to the program."77 The training system is aimed primarily at the Middle East market, although it has also been presented to the United States Air Force and Navy.

Barter arrangements are now commonplace when customers have insufficient hard currency. Malaysia, for example, is paying for between 16 and 18 MiG-29s partially with fabrics, finished clothing, and palm oil. Russia has also raised the possibility of building facilities for the processing of palm oil as part of the deal.78 Russia has promised that these MiG-29s will have better lifetime performance for their RD-33 engines, extended airframe life, avionics packages adapted to Malaysia's humid climate, and government assurances about product support, maintenance, technical services, and parts manufacturing through a dedicated local company or joint

77 "U.S.-Russian Team Offers Fighter Training," Aviation Week and Space Technology, 1 November 1993, pp. 49-52.

partnership.\textsuperscript{79}

The issue of distribution of revenue has still not been resolved. The Mikoyan design bureau, for example, was promised a substantial share of the proceeds if the MiG-29 deal with Malaysia went through, but that promise is as yet unkept.\textsuperscript{80} It is still the case that most hard currency revenue from aircraft deals goes to the government, and the rest to production facilities, not the design bureaus and research institutes. In fact, the production facilities are currently doing much better than the design bureaus, since the former can convert more readily to contract work; they have a product that can be bought and sold. The research institutes stand in even worse stead than the design bureaus for the same set of reasons.

According to most accounts, the Sukhoy design bureau is in somewhat better shape than Mikoyan, primarily because it produces more saleable products. Su-27s, for example, have been exported to China, and the company has been providing support to the Chinese Air Force for the introduction of the aircraft into service. Sukhoy also has always produced sports/aerobatic aircraft, which Simonov describes as now "of paramount importance."\textsuperscript{81} In addition, Sukhoy is still

\textsuperscript{79} Michael Mecham, "Malaysia Buys MiG-29s, F/A-18Ds," Aviation Week and Space Technology, 5 July 1993, pp. 24-25.

\textsuperscript{80} Interviews.

\textsuperscript{81} Simonov, interviewed in Chernyshov, 17 December 1992, p. 6.
producing the primary Russian Air Force fighter; it won an official competition to play that role in 1989-1990, although that decision has never been officially announced. The Su-27K also won over the MiG-29K as the base for a carrier-based aircraft.\textsuperscript{82}

**Self-financing and Cost-accounting.** Conversion was initially a particularly bitter pill for defense enterprises to swallow because of the regulations introduced in the late 1980s on enterprise self-financing and cost-accounting.\textsuperscript{83} Cost-accounting essentially meant that enterprises were expected to balance their budgets in monetary form. Self-financing, which required enterprises to meet their own expenses through revenues, was its backbone. Enterprises therefore had to cover their own expenses for raw materials and other supplies, wages, various production and incentive funds, and taxes, through either sales or credit. The state would no longer subsidize unprofitable firms, nor would it guarantee wages or a market for all goods produced.

Cost-accounting operated according to a series of theoretical principles:\textsuperscript{84}

1. The enterprise enjoys a wide range of managerial and

\textsuperscript{82} Interviews.


economic independence. It may set wages and labor policy as it pleases. It may also conclude economic and material contracts with other enterprises without state intervention. Finally, it is welcome to accept credit from any bank on terms to be determined between the enterprise and the bank.

2. The enterprise will therefore have a material interest in the results of its own economic activity. Its net income, after payment for necessary inputs and taxes, will be designated the "khozraschet income." This sum will be at the disposal of the enterprise to distribute as it sees fit between wages, various incentive funds, investment, and financial reserves. Ideally, this sum will be distributed so as to maximize each worker's interest in the quality of his own personal contribution to the output of the enterprise.

3. The members of the entire enterprise, or of enterprise departments, will be held materially accountable for failure to produce necessary results. Fines will be levied on the khozraschet income for violations of state standards of price, quality, and other norms. Similarly, fines will be issued for breach of contracts concluded with other organizations or enterprises.

4. The state will prevent contradictions between the individual interests of enterprises and the needs of society as a whole by balancing broad centralized planning with the independence of the firm. This balance will be maintained through state control figures, state orders, and long-term stable economic norms.

5. Socialist self-management guarantees the participation of each worker in economic decision-making. Workers, who comprise the "General Conference," will approve the enterprise's basic economic plans and activities. The General Conference also elects the "Council of Workers Collective," which fulfills those functions on an everyday basis.

These arrangements were designed to expand decisively the operational and economic independence of enterprises by allowing them full disposition and control of the means of production. The enterprise, in theory, had the right to make its own economic and managerial decisions, and in turn it had the responsibility to finance such arrangements by its own
devices and to fulfill completely all economic agreements it entered into. The goal was for the enterprise, and in turn each worker, to accept greater responsibility and accountability for the quantity and quality of their work.

The combination of conversion and the new demands for enterprise self-financing had several dramatic consequences for the defense sector. One had to do with the start-up costs for conversion. Because of the new self-financing regulations, most defense enterprises received no government money or resources for conversion; the substantial amount of retooling necessary for successful conversion had to be self-financed from existing enterprise liquid assets. Enterprises could borrow money from the state bank or any of the newly formed commercial banks, but most managers were hesitant to risk a loan at such high interest rates (83% as of September 1992) at a time of such great economic uncertainty. They feared that their enterprises would not be able to acquire the necessary supplies to maintain production and therefore might not be in a position to repay large outstanding debts.

In order to understand the difficulties of self-financing and the transition to contract and market relations, we must understand the dual nature of the Russian currency, the ruble,

85 Rising inflation has certainly increased that rate even more since the end of 1992. See interview with Anatoliy Mikhaylovich Petrov, general director of the Komsomolsk-na-Amure Production Association, by Col. Aleksandr Andryushkov, "Ne konversiya rozhdayet bezrabotitsu...," Krasnaya Zvezda, 30 September 1992, pp. 1, 2.
during the Soviet period. Stephen S. Moody of the Center for Post-Soviet Studies has offered the most comprehensive available account of this phenomenon.\textsuperscript{66} Moody explains that there were actually two rubles: the cash, or "nalichnyi," commonly-recognized ruble; and the "beznalichnyi" ruble used solely as an accounting device by state-owned industry and government monopolies. The former circulates among the population, but its purchasing power and hence its real value was limited because of the narrow range of goods and services available with it. The accounting ruble was the only currency that could purchase raw materials, bulk commodities, or even most manufactured goods at wholesale prices, but even this ruble had no value unless it was accompanied by a state-issued certificate allocating the transfer of goods from one state enterprise to another. This was largely a consequence of the structure of the centralized planning system: because of constant shortages of a large number of commodities, goods were allocated by the government in the annual plans not by their ruble values, but in material quantities. The ruble in the wholesale, interenterprise sense was therefore merely a post-facto accounting mechanism, not a genuine instrument of exchange carrying real, discernible value.\textsuperscript{67}


\textsuperscript{67} For details on how this worked in the defense sector, see Stephen M. Meyer, "Economic Constraints in Soviet Military Decision Making," in Henry S. Rowen and Charles Wolf, Jr., The Impoverished
This system meant that the Soviet government could in effect assign different ruble values to different commodities, frequently having little to do with actual supply and demand. Since top political priority was consistently afforded to the defense sector, this meant that defense enterprises could be "charged" fewer rubles for the exact same material inputs that might command a completely different "ruble" price in another, less politically important industry. In another words, according to the accounting ledgers, a ruble might buy significantly more steel for a tank factory than it could for a tractor factory. According to one Russian analyst, the purchasing power of the ruble in the defense sector was three times as high as in the machine building sector, and nine times as high as for consumer goods production.\textsuperscript{88} The only entries on the defense industries' books that dealt in "real" rubles were those that involved those rubles directly, such as wages and labor-intensive research and development.

This system has still not been completely dismantled. The 1987 laws that theoretically abandoned it in favor of enterprise "self-financing" did not prevent state monopolies, which have not yet been privatized, from continuing to denominate the raw materials they process in "accounting" rubles at special state prices. Many of these monopolies are

in the defense sector or supply it, which means that they still lack incentives to respond to the market reform efforts. When state retail prices were decontrolled in January of 1992, for example, accounting-ruble prices were raised but still fixed by the government; this implies that the market forces supposedly unleashed by the freeing of prices were not felt by a significant segment of Russian industry.

Most defense enterprises, however, were forced completely out of their privileged financial position, at the same time that their defense orders were cut and they were expected to undergo independent conversion to civilian product lines. This meant that, for the first time, they were expected to pay "real" ruble prices for their material inputs, resulting in dramatically increased prices for the defense equipment that was produced and exacerbating the sharp decrease in military-related output. The fact that the structure of Soviet industry in general was so heavily monopolized meant that sole producers of vital commodities could demand outrageous prices in the newly-developing market environment and get away with it; their customers had nowhere else to turn. Often these monopolies were able to extort payment in currency other than rubles: Western European cars, Japanese consumer electronics, and other high-quality foreign consumer goods.

Supply difficulties. Supply problems were another of the biggest headaches to converting enterprises. Even non-converting enterprises are now having difficulties maintaining
supply lines; with the Council of Ministers staff cut by 32% from 1989-1991, and some defense ministries by as much as 50%, the managerial infrastructure to dole out supplies from the center simply no longer exists.\textsuperscript{89}

It has been tremendously difficult for converting defense enterprises to operate under conditions of "economic anarchy," where the traditional administrative economic system has largely disappeared, but a market has not yet taken its place.\textsuperscript{90} With the ruble internally inconvertible, and its purchasing power highly questionable in any case, the defense industries have found the task of setting up their own supply lines to be a nightmare. They cannot simply take their rubles out to the marketplace and purchase the new supplies they need. It is by far their most prevalent complaint about conversion. They are accustomed to operating in a radically different world in which desired results were to be obtained regardless of costs, and in which, as discussed above, the stress was more often on gross output than on response to demand, quality, output mix, etc.\textsuperscript{91} A vital element of this system, of course, was priority access to supplies. Now, with


military orders slashed, the quest for supplies to set up new civilian production lines has become all-consuming.

Restrictions on the level of profitability of defense enterprises are also harming their ability to purchase adequate supplies to maintain their production lines. Current law holds the level of profitability of defense products to 25%, but there are no such regulations affecting the civilian producers of component parts and raw materials. Since many of those enterprises are still monopolies, they can charge any price they please for their products -- there are no alternate sources to which the defense facilities can turn.92

Horizontal ties. The woefully infantile state of development of horizontal ties between Soviet industrial producers has meant that converting defense enterprise seeking particular inputs have no idea where to look. Indeed, at one 1991 conference of defense industry representatives and other defense and civilian ministry officials in Kiev, Ukraine, it was clear that such horizontal communications between converting defense enterprises, their potential and desperately needed suppliers, and equally important, their potential customers, have been practically non-existent.93 These defense industrial representatives are, of course,
natural business associates, located largely in the same city, and yet it was clear that they were encountering one another for the first time at a conference organized and run by Westerners. The historical horizontal separateness imposed by the ministry structure has obviously continued to hinder the development of anything resembling a functioning wholesale market.

Indeed, some suppliers who produce goods they suspect converting defense enterprises might need have wondered where all the customers are. One plant manager reported that, although his factory is virtually the only one in the country that makes a special type of rubber essential for food industry machine building equipment, he had received no orders from defense enterprises.\(^{94}\) In many cases, suppliers are simply continuing to fill the standing orders which were relevant for the pre-conversion product mix of defense enterprises. The defense customers fill warehouses with this now-useless material, leaving them with tons of surplus stock and still no ability to produce new civilian goods.\(^{95}\) For example, one Volga electronics firm has been left with three million rubles in unusable equipment, 1.5 million rubles in dead freight, and 700,000 rubles in half-finished goods. All


together this amounts to five million rubles in "ballast," a huge loss for any business to swallow.\textsuperscript{96}

Some firms have begun to pursue ad hoc methods of building these horizontal ties. As predicted by resource dependency theory, enterprises are trying to alter an unpleasant environment by forming coalitions which help them all to achieve greater independence from that environment. A Military-Industrial commodities exchange has been formed at the Flight Control Center near Moscow to help military industrialists develop a wholesale market. An even more comprehensive permanently operating national commodities exchange, where representatives from Gosnab, territorial administrators, and key plant officials can meet and conclude contracts, has been established in Donetsk.\textsuperscript{97}

Even when customers and suppliers do manage to locate one another, it seems that Soviet industrial contracts today are seldom signed without the addition of strenuous "extra-economic" conditions. One aircraft designer reports that suppliers are demanding such "extras" as loads of lumber, Japanese video equipment, and European cars in addition to standard ruble (or hard currency) payments to augment the social programs of their own enterprises and labor

\textsuperscript{96} V. Zhuralev, "Sdelano v p/y a no...," \textit{Ekonomicheskaya Gazeta}, No. 50, December 1989, p. 9.

collectives. 98 Because of the monopoly position of many suppliers, the customer usually has no choice but to submit to this "stone-age barter." 99 Indeed, the monopoly problem is so bad that one scholar estimates that 77 percent of the production lines in the machine building, metallurgy, chemical, timber, and construction industries are supplied by only one producer. 100 In other words, monopoly enterprises are taking full advantage of the resource dependency not only of the military services who place orders with them, but of the other enterprises they supply on the wholesale level. Sometimes the customer enterprises have to dig deeply into their own economic stimulation funds to manage these payments; even this extortion, however, usually leaves the defense enterprises better off than if they produced no civilian output at all, given the reduction in military orders. 101

Already some defense enterprises are suggesting that it might be more efficient for them to develop their own internal sources of supply for these items, completely isolating themselves from an undesirable environment as resource


dependency theory would predict.¹⁰² One major defense production association, for example, recently purchased a timber processing plant and a brick factory for its own use.¹⁰³ This solution, however, does not allow for specialization and economies of scale, and forces the defense enterprises to bear the start-up costs for the production of these materials and component items.

In many cases, converting defense enterprises are forced to buy materials from abroad. The necessary hard currency, however, can only be obtained by selling products above the plan, and when enterprises manage to accomplish this feat, their ministries often accuse them of hoarding unused stocks and allocate even fewer supplies to them in the next plan cycle.¹⁰⁴ The defense enterprises find themselves the victims of a vicious circle.

Military aircraft production still relies on the old Gosplan/Gossnab-dictated supply lines.¹⁰⁵ The disintegration


¹⁰³ Interviews.


¹⁰⁵ Interviews.
of the Soviet Union has exacerbated this problem, since Russian producers no longer have access to their old non-Russian suppliers. According to a deputy chairman of the Russian Committee on Defense Industry, even though Russian inherited almost 80% of the defense industry capacity of the former Soviet Union, it can produce only 17% of the military hardware it needs without inputs from other, now newly-independent, states.\footnote{RFE/RL Daily Report, No. 235, 9 December 1993.} For example, Kiev's Antonov Design Bureau can no longer effectively work with its aircraft's producers, who are located in Russia; similarly, the Tupolev Design Bureau's aircraft, developed in Moscow, are manufactured in the capital of Uzbekistan. When designers and producers manage to maintain communication and business ties, the old economic arrangements are being abandoned; as Victor Tchouiko, the president of the Association of Aviation Engine Manufacturers explains, "Aircraft industries in all the republics are trading between each other at world prices." Coupled with the repeated taxation of components as they are moved between states, this has resulted in a "crazy situation." Aviaprom's President Vladimir Ivanov agrees: "These are artificial problems created by people who don't understand. I've worked 40 years with my comrades from the Ukraine."\footnote{Quoted in Douglas Barrie, "Russian Roulette," \textit{Flight International}, 2-8 June 1993, pp. 23-24.} At minimum, these industrialists would like to
see the restoration of duty- and license-free movement of completed items across borders.

Price-setting. Some of the converting defense enterprises' difficulties also have to do with the way prices have been historically set for defense industry output. A. Isayev, an official of the Ministry of Aviation Industry, argues that for years defense enterprises have received prices far below the actual value of the goods produced. Under the old administrative system, these prices were virtually irrelevant, since the "profitability" of working in the defense sector was measured through indicators other than ruble expression of profit: priority access to supply, high wages and other perquisites for workers, access to foreign technology, etc. Self-financing, however, has meant that enterprises across the board are expected to balance inputs and outputs on a ruble basis, and the low prices paid for military products have left many defense enterprises in disastrous financial condition.\(^ {108}\) Now that defense enterprises must balance revenues and expenses in a budget expressed in monetary terms, the old prices are frequently much too low even to cover production costs, let alone generate a profit.\(^ {109}\) This is particularly true in light of


\(^{109}\) For an excellent discussion of this phenomenon, see George G. Weickhardt, "Recent Discussions of Defense Economics," Report on the USSR, March 9, 1990, pp. 9-13. See also Boris Varisovich Salikhov, Candidate of Economic Sciences and Lecturer in the
the fact that prices for basic raw materials, such as energy and fuel, are rising across the board at the same time that many defense subsidies end. One source predicts that wholesale prices in Soviet industry as a whole could rise over the next year by as much as 46%, with fuel and energy prices increasing by 82%, metallurgical prices by 71%, and chemical and timber prices by 64%.\textsuperscript{110} This line of argument certainly explains recent reports that the prices of some military equipment have risen over recent years by 100-200 percent and more.\textsuperscript{111} Defense-related prices are also increasing because of rising overhead costs resulting from shorter military production runs,\textsuperscript{112} because the reduced orders usually affect older types of military equipment which have been in production for many years and which have consequently relatively high profit margins, and because the new civilian production lines must share overhead expenses with the old

\textsuperscript{110} A. Komin, Doctor of Economic Sciences and First Deputy Chairman of the USSR State Committee on Prices, "Reformatsenoobrazovaniya: chto vperedi?" \textit{Krasnaya Zvezda}, June 6, 1990, p. 2.


defense production. Another problem has to do with rapidly changing prices. An official of one defense production association in Minsk explains that the main difficulty enterprises are having in preparing for future production is in knowing what prices to use in calculating future plans.

Self-financing for research and development. Self-financing and cost-accounting have generated the most controversy when applied to organizations carrying out basic research and development. Fiscal allocations from the state budget for basic defense research have been cut drastically in recent years; the Chief of the Central Institute of Aviation Motor Building claims that he cannot now afford even to run his test bed. One military academy director reports that, at his institute, the state now allocates only 40 rubles per year for research equipment, materials, etc.

Research organizations are expected to compensate for the loss of direct state funding through contract work. The

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114 V. A. Baraznenok, Deputy General Director of the Minsk Production Association, in Planovoye khozyaystvo, April 1990, pp. 100-105.


116 Interview with Major General Yu. V. Kryuchkov, Deputy Head of the Military Academy imeni F. E. Dzerzhinskiy, "'Ne uvesti korabl' nauki na melkovad'ye'," Krasnaya Zvezda, July 1, 1990, p. 2.
scientists, however, argue that if users contract with basic research organizations for science as a product, then they will demand immediate results. Science does not always work that way, however; how, and when, can "results" be defined? The real value of scientific work is not always immediately evident. In addition, even when research enterprises manage to come up with new, applicable, money-making innovations, the patents under current arrangements are usually granted to whomever is the first to transform the science into hardware. There is virtually no protection for designers' rights. This makes it practically impossible for basic research institutes to finance their work through commercial applications, unless they shift their efforts to applied science and product development. Of course, if all science is applied, then soon there will be no basic science left to apply.

Under the current situation, it is also feared that, without steady wages, all the best Soviet scientists will migrate to the best "income" sciences, or will go to the West. Among those who remain, cost-accounting and self-financing for basic science may stifle the cooperation and

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119 Interview with Major General Yuriy V. Kryuchkov, "Ne uvesti korabl' nauki na melkovod'ye, Krasnaya Zvezda, July 1, 1990, p. 2.
communication that is essential to a healthy scientific community. If research is a commodity to be paid for on the market, then knowledge will become a property, jealously guarded. Clearly, therefore, cost-accounting and self-financing are wholly inappropriate for basic scientific research. Even if contract revenues could cover scientists' wages and day-to-day operating costs, they cannot cover the cost of expensive scientific equipment. One source suggests the formation of a government-sponsored leasing house, or even better, an arrangement where time can be "bought" on such equipment, like supercomputer time is frequently purchased in the West. Arrangements such as these, while certainly likely to be beneficial, will still not resolve the basic problems outlined above. The haphazard nature of economic reform and its impact on the defense industries has engendered great uncertainty about the future for many weapons system designers and producers.

The Search for Private Capital

Because of the lack of government funding, many of the defense industry enterprises have been searching for alternate


sources of capital. Some analysts have suggested that the design bureaus themselves might merge, but this seems rather unlikely. Over the years, the major players in Soviet aviation design have established unique reputations, and most of them appear prepared to "wither and die" rather than to merge with their competitors.\textsuperscript{122} The design bureaus have, however, aggressively begun to try to take advantage of the production associations' better positions. Belyakov explains, for example, that Mikoyan has moved to create "MIGservis," an organization that combines the design bureau with one of its major manufacturing plants, the Znamya Truda (Banner of Labor) facility.\textsuperscript{123} No intermediaries therefore interfere with the delivery of aircraft and spare parts to the customers; the team cooperates with only one foreign trade structure for licensing and sale of the aircraft. Some analysts predict that these types of arrangements could eventually result in the weaker design bureaus simply being absorbed by their stronger, wealthier production affiliates. The Yakovlev design bureau has done the same. Sukhoy has gone even further, crossing former republic boundaries to correct organizational deficiencies. It has former "Shturmoviki Sukhogo" (Sukhoy's Ground Attack Aircraft), a structure that


unites the Moscow design bureau with its primary Su-25 production facility in Tbilisi, Georgia. After primary assembly in Tbilisi, the aircraft flies to Russia for finishing production touches and preparation for sale.\textsuperscript{124}

CIAM has moved to privatize some of its assets, creating more than twenty small companies within its overall organizational umbrella. The hope is that these smaller, commercial structures will provide more motivation for personnel to seek new business independently and therefore earn more money.\textsuperscript{125} The All-Russian Institute of Aviation Materials (VIAM) has done the same. Its procedure, as described by one of its directors, is that VIAM develops a new material and application, spins off a new daughter company, and purchases any additional materials and expertise necessary to make the project viable; the new daughter company then manufactures and markets the product in a joint venture with VIAM itself.\textsuperscript{126} VIAM owns 51\% of each of these companies, of which there are currently about 15, all located on-site at one of VIAM's main buildings. This makes it difficult for the new companies, once established, to "defect" away from VIAM itself. Not only does the activity of these new companies encourage workers to stay at the research institute, since it gives them more income and freedom to do the kind of work they

\textsuperscript{124} Interview with Babak, 26 November 1992, p. 6.

\textsuperscript{125} Lenorovitz, 20 April 1992, p. 50.

\textsuperscript{126} Interviews.
want to do, it gives VIAM the money to continue providing "extras" to its staff: day care and kindergarten for workers' children, holiday centers, etc. Of course, this arrangement merely skims the cream of the research institute's talent off the top of its main body, diluting the focus and orientation of the institute as a whole.

The aircraft enterprises are also trying to bring in capital from private investors. The directors of a number of leading aviation enterprises in 1992 formed the Russian Aviation Trade Center (RATD), an open, joint-stock company. Membership includes designers from the Mikoyan, Sukhoy, and Yakovlev design offices, eight aircraft plants, the Aviatrans production association, the Aviaspetssnabsbyt company, Aviabank, the Scientific Research Institute of Economics, and the Brokinvest brokerage. The latter handle the issuing of shares for the company. The initial charter capital was 14 million rubles, but when a number of other organizations expressed an interest in becoming stockholders, that figure jumped to 25 million. With a face value of 50,000 rubles, RATD shares were trading in mid-1992 at 350,000 rubles on the open market. The center's prime objective is converting the member producers' capabilities toward civilian goods that can be sold on the domestic and foreign markets. However, since that technical process will take years and a great deal of

money, in order to preserve the plants' personnel teams and physical infrastructure, RADT is also helping the producers to remain capable of stable exports of combat aircraft. The trade center coordinates this conversion work, receiving information on market opportunities for aviation equipment (demand) and proposals for new models from the design offices (supply). Its expert teams then conducts an appraisal of both sides of this equation, with its own staff and funds, and recommends which civilian projects should be funded. RADT therefore performs the function of the market for designers and producers who are accustomed to centralized planning, and are simply incapable of determining for themselves promising areas for civilian product development.

Some design bureaus have been given a tentative green light to move ahead with privatization. Sukhoy in particular, early in 1993, received permission from the Russian Committee of State Property for the sale of half of its shares to company employees. This effort had been previously stopped by the Russian government because Sukhoy had been on the list of companies forbidden to privatize due to national security considerations. Following numerous requests and intensive lobbying from Sukhoy's management, Vice Prime Minister Anatoly Chubais signed a compromise agreement calling for a three-year transition during which Sukhoy may privatize. This deal was

128 Interviews; see also Boris Rybak, "Russians Advance Privatization Plans," Aviation Week and Space Technology, 29 March 1993, p. 60.
subsequently modified to two years, with 30% of the stock to be sold in 1993 and the remaining 20% in 1994. Of the remaining shares, 25-29% are to be held by a state agency for 2-3 years, and the rest is uncertain. Tupolev, Mil, and Kamov were also given the go-ahead to formulate privatization schemes earlier in 1993; the youth of the endeavor makes its exact structure and procedures difficult to anticipate. It appears that the design bureaus are trying to maintain a very high valuation of their assets, and have tried desperately to keep the shares among their own management and employees.\textsuperscript{129} On 4 December 1993, State Property Committee Chairman Anatoliy Chubais announced that Yeltsin had approved the privatization of up to 80 percent of defense enterprises, with 50% of the shares offered on preferential terms to plant employees, 29% auctioned for vouchers, and 20% auctioned for cash.\textsuperscript{130} About 450 plants -- those considered the "most important" -- will remain in state hands.\textsuperscript{131}

Anything that might bring in money, particularly hard currency, seems fair game. The Moscow Aviation Institute, for example, has created the Moscow International Aviation School, which will offer a technical course for foreign students form July through September 1994. Former Sukhoy designer Oleg

\textsuperscript{129} Interviews.
\textsuperscript{130} RFE/RL Daily Report, No. 232, 6 December 1993.
Samoylovich will be the director of the institute.\textsuperscript{132}

Clearly more and more aircraft designers and producers are also hoping for foreign capital to get them through this difficult period. TsAGI's future is increasingly tied, for example, to international orders. It began to offer its facilities, which include 36 wind tunnels, test chambers, and simulators, to foreign contractors in early 1991. Deals with Britain, the United States, France, Germany, India, China, Korea, and Italy generated $1.5 million in revenue for the research institute after twelve months.\textsuperscript{133} The largest number of contracts involves the use of TsAGI's T-128 transonic wind tunnel, which is capable of testing from Mach 10–20 and features adaptive walls. One contract with Boeing involves testing of an entire wing section.

A particularly popular match has been Russian airframes and Western powerplants. Snecma, Paris, a French firm, for example, will supply its Larzac 04R20 turbofan engines to power Mikoyan's new MiG Advanced Trainer (MiG-AT).\textsuperscript{134} Ultimately the deal could involve more than 2,000 engines worth as much as $3 billion including spares. Under the agreement, the Larzac engine will be built under Russian license for the Russian Air Force aircraft, but will be

\textsuperscript{132} Lenorovitz and Rybak, 27 September 1993, p. 55.

\textsuperscript{133} Morrocco, 13 April 1992, pp. 60–61.

supplied from Snecma's French production line for aircraft intended for export. The MiG-AT is competing with the Yakovlev design bureau for a 700-aircraft Russian order for a new trainer; a decision is expected by early 1994. The French and Russian firms view Asia as their primary export market.

Some Russian officials worry, however, that this collaboration will further damage an already weak base in Russian propulsion research and design. Other recent deals may assuage those concerns, however. Pratt & Whitney Canada and the St. Petersburg-based Klimov Corporation, for example, have just signed a contract to codevelop and produce turbine engines for the former Soviet and Eastern European market. Pratt will hold a 51% share in the deal, with the remaining 49% controlled by Klimov. The collaboration will initially focus on Pratt's PT6A-67R turboprop power plant and the PW200 family; the vice president of Pratt Canada estimates the local market for these engines at around 5,000 units. One potential use is on the new high-wing, twin-engine MM-1 transport being cooperatively developed by teams from Russia and Germany: Russia's Myasishchev Design Bureau, the Smolensky Aircraft Plant, and the Munich-based Tech Avia management-financing group.¹³⁵

Mikoyan is recognizing that part of its foreign market might be for upgrades of old Russian aircraft currently in service in other countries. To that end, Mikoyan has teamed

¹³⁵ See Lenorovitz and Rybak, 27 September 1993, p. 54.
with France's Thomson-CSF to offer modernization of the MiG-21, including installation of the French company's latest radars, electronic warfare suites, cockpit displays, and navigation systems.\textsuperscript{136} The firms will jointly prepare proposals for upgrade contracts; Mikoyan will assume technical responsibility for the upgrades.

Chief Designer Mikhail Simonov at Sukhoi has even suggested collaboration with Mikoyan and with the United States on a next generation of combat aircraft. Simonov believes that, although seemingly far-fetched now, once the current crop of fighters -- the Eurofighter, the Rafale, the Gripen -- enter service, there will be a European market for a new, heavier fighter in the F-15/Su-27 weight class. He would like to exploit this market. If, however, the United States or Russia were to undertake development of a next-generation fighter alone, the other would have to ask "against whom it is directed."\textsuperscript{137} A joint development, however, would end "the ideology of confrontation" once and for all. Sukhoi, although in a relatively stable position because of Simonov's success in turning 50% of Sukhoi's business to commercial endeavors, needs to open new business channels to remain afloat. Most of those Sukhoi civilian aircraft are advanced

\textsuperscript{136} "Industry Outlook," \textit{Aviation Week and Space Technology}, 5 July 1993, p. 17.

aerobatic aircraft, for which there simply is not a sufficient market to sustain the entire design bureau. Production of the Su-27 remains Sukhoy's mainstay; once that production line ends, Sukhoy will find itself in the same situation as Mikoyan.

Mikoyan has also approached the United States military establishment, having teamed with the Belgian firm Promavia to enter an open international competition to provide trainer aircraft for the United States Air Force. If the team wins, it will provide the primary American trainer aircraft. Promavia had already developed a prototype, and brought Mikoyan into the deal to further develop the design. All technical activity on the project, including selection of design parameters, calculations for durability, and testing, has been transferred to the Russian side; Promavia handles marketing, financing, and general organization. Production is similarly internationalized. Russian plants will produce primary assemblies, with finishing taking place at Belgian plants in Canada. The use of Russian components in the aircraft will significantly reduce their cost, which, the team hopes, will increase its competitiveness in the U.S. procurement competition. It is predicted that operation of the Russian-Belgian trainer will cost about $260 per flying hour, as opposed to current Western designs with flying hour

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costs of $600-800.

Some Russian research institutes seem to have realized that the best way to penetrate Western markets is to form joint ventures with Western firms. VIAM, for example, currently has three joint stock partnerships with the United States, all based on U.S. territory, two of them with 51% U.S. ownership, and one a 50-50 partnership. VIAM tries to stress trade not in raw materials, but in actual finished consumer goods it produces from its materials research. These partnerships are:\textsuperscript{139}

* VIAMEXportech Ltd., based in New York, which sells light metals for automobile engines, aviation engines, and machine building, 99% for the U.S. market;

* VIAM USA Corp., a scientific center based in Houston, which markets VIAM-developed materials in the United States, and tests materials; and

* Kaiser-VIAM Ltd., a 50-50 partnership which works with VIAM USA to market materials in the United States.

Working with U.S. based partners helps VIAM to master the American legal system and also to make potential American partners and investors more aware of the business and legal situation in Russia. VIAM also has contracts with Boeing to participate in the Boeing research center in Moscow, and is exploring links with Rockwell and Teledyne.

After a year or two of initial contact, Russian aerospace officials have begun to demand proof of available capital before revealing certain technologies and demonstrating

\textsuperscript{139} Interviews.
products to visiting Western entrepreneurs. Russian officials are justifiably concerned that their desperate need for Western capital has made them an easy target for disingenuous visitors. 140

On the other hand, until Russian enterprises and managers learn to be more professional in their dealings with Western firms, their benefits from these partnerships will be limited. Potential Western partners have been frustrated by doubts about who owns what, who has authority to sell it, how valid signed contracts turn out to be, and a lack of recourse when contracts are not fulfilled. Even basic information about research and production facilities -- names, addresses, phone numbers -- have not been part of the public record during the Soviet period; Russian officials are still in the early stages of such rudimentary marketing activities as compiling an aerospace directory. Their early track record at critical events like international trade shows has risked earning them the label of nuisance. At the June 1992 International Aerospace Exhibition in Berlin, for example, Russian exhibitors unexpectedly billed their German hosts not only for the standard travel and living expenses, but also for their personnel salaries during the time of the show, rent for their stands, and a daily rent for the equipment they brought. The bottom-line cost to exhibit sponsors was over $150,000, with

the Russians' demand for even more quelled only when they were told that unless they compromised, German companies interested in potential joint ventures might reconsider.¹⁴¹

Western aerospace CEOs and other senior international personnel also sharply criticized the manner in which Russian exhibition managers staged the Moscow Aerospace '93 show in August-September 1993. The primary problem was that one exhibition was in downtown Moscow, and a second was a two-hour drive away at the Zhukovskiy flight research center; a third display on historic aircraft was largely ignored. The two major sites engaged in cut-throat competition for attendees and resources before and throughout the show; timely travel between the two was impossible, and neither would recognize the other's credentials. Apparently this behavior had to do with each groups' efforts to win a future monopoly on air shows in Moscow.¹⁴² In addition, most Russian displays at both sites were grouped in a separate building from those of the other participants, and their placards were printed only in Russian. Furthermore, most U.S. and Russian exhibitors noticed that the Russian stands were essentially the same ones they had seen two months earlier at the Paris Air Show and


less than a year before at Farnborough.\textsuperscript{143} Apparently many Russians simply do not understand the appropriate motivations for hosting such an international event; Nikolay A. Zanegin, vice general manager of the Zhukovskiy site, said, "The real reason for having another Moscow air show now is to give us another reason to help keep our engineers from leaving."\textsuperscript{144}

\textbf{Blat' Lives: The Importance of Personal and Political Connections}

Increasingly, it seems to be the case that personal ties and political skill play an enormous role in determining the fate of Russian defense industrial establishments. In fact, one close observer claims that virtually everything currently hinges on interpersonal and political relations; "frankly speaking, we have no industrial laws."\textsuperscript{145} In early June 1993, the top managers of Russia's five major aerospace research centers -- TsAGI (the Central Aero-Hydrodynamics Institute), LII (Zhukovskiy Flight Research Center), TsIAM (Central Institute of Aviation Motors), CIAM (All-Russian Institute of Aviation Materials), and the Central Aviation Systems Institute -- proposed to Yeltsin a total restructuring and

\textsuperscript{143} "Russian 'Troika' Air Show a Mistake," \textit{Aviation Week and Space Technology}, 6 September 1993, p. 68.

\textsuperscript{144} Quoted in Craig Covault and Boris Rybak, "Russia Revamping Aerospace Identity," \textit{Aviation Week and Space Technology}, 7 June 1993, p. 61.

\textsuperscript{145} Interviews.
consolidation of the Russian aerospace industry. Design bureau managers, although aware of the meeting, did not participate, preferring to let the research establishment argue their case.146 This has most to do with the political clout of German A. Zagainov, TsAGI's director. Zagainov was closely aligned with Yeltsin even before Yeltsin won the Russian presidency; he enjoys a reputation as one of Russia's most clever, business-oriented individuals.147 The defense research and design establishment's plan centers on the consolidation of major Russian aerospace industry plants, research facilities, and design bureaus on a regional basis and with a common business structure. The latter would include more formal use of the U.S. dollar as the planning currency, a currently common but unofficial practice. The plan also seems to fall in line with the slower economic reform preferred by many in the old Supreme Soviet. The comment of Igor Y. Katyrev, chief designer of the Ilyushin design bureau, was typical: "You don't need to scrap the whole building when you are going to repair your house."148

Meanwhile, throughout early 1993, Russia's top bomber and fighter designers, in particular Belyakov from Mikoyan and Youly Kashtanov from Tupolev, were approaching Yeltsin with a


147 Interviews.

plan to restart production of new Russian front-line fighters, including flight testing of the Mikoyan F-22 clone. This intense lobbying illustrates the unusually direct access and influence senior aircraft designers have with the Russian president, and the apparent weakness of the Ministry of Defense. Some of the design bureaus have even created lobbying companies to pressure the Russian government to increase military R&D allocations, but as far they have not been successful.

A panel of leading air force, government, and industry figures followed with a September 1993 draft plan to establish key Russian Air Force programs into the 21st century. Their hope is to provide some certainty to planning processes, and hence to stem the chaos that has beset the defense and aerospace industries. Since approximately 1988, military aircraft and helicopter programs have moved in and out of favor almost on a monthly basis, creating poor morale and an inability to plan ahead in design bureaus and production facilities.

Apparently the favored position of the Sukhoy design bureau has much to do with the political clout of its chief designer, Mikhail Simonov. Simonov has carefully and


150 Interviews.

skillfully cultivated and exploited his good relations with the government, having sat on the first USSR Supreme Soviet Committee on Defense and State Security. Some sources claim, however, that his influence peaked in 1988-1989, and has been declining ever since.\textsuperscript{152} His only real strong point recently has been persuading the government to keep his military and civilian aircraft production lines open because of their export potential. After limited success on the international market, however, Simonov's influence is waning; right now, only those companies who have a proven track record in the international aircraft market are getting real support from the government.\textsuperscript{153}

Even so, the perception that some design bureau heads are lobbying for particular favors for their own institutions has led to sharp infighting between the design bureaus. As one observer put it, "now that there is no food left, the rats are starting to eat each other."\textsuperscript{154} Mikoyan's Belyakov simply does not have the political savvy and connections of Simonov. Mikoyan's MiG-31M has been that design bureau's best hope for survival for the last few years; unfortunately, that hope stemmed from the air defense forces' desire to maintain their "own" design bureau, and the recent air force/air defense

\textsuperscript{152} Interviews.

\textsuperscript{153} Interviews.

\textsuperscript{154} Interviews.
restructuring leaves Mikoyan without a powerful patron.155

In some senses, the government has encouraged this infighting by introducing, for the first time, some measure of competition into procurement decisions. For example, the Yakovlev, Mikoyan, Sukhoy, and Myasishchev design bureaus competed for the design of the air force’s next advanced jet trainer aircraft. Only the first two firms survived the initial cut, and Yakovlev won the final round. The air force had originally intended to conduct a flyoff between the two finalists, but there was insufficient funding for two prototypes, and therefore only Yakovlev’s winning design will be translated into a flying prototype.156 Sometimes, however, the old ways persist. Even though, for example, the single-seat Kamov Ka-50 attack helicopter was selected over the twin-seat Mil Mi-28 design in an unofficial Russian Army and Air Force competition in mid-1992, the Russian Ministry of Defense has decided to buy both systems.157 Apparently the dual purchase was prompted by protests from the Mil design bureau, even after two additional fly-offs, both of which the Kamov design won again;158 the Russian government clearly is not yet

155 Interviews.


157 Craig Covault and Boris Rybak, "Russian Helicopters Spark Controversy," Aviation Week and Space Technology, 12 June 1993, pp. 52, 55.

158 Interviews.
ready to suffer the unemployment likely to result from the shutdown of major aircraft design and production lines.

Predictions Revisited: Conclusions About the Former Soviet Union

The Soviet/Russian procurement dynamics reveal some distinct patterns in relation to the predictions from the various theories under examination. The Cold War-era Soviet Union clearly undertook extensive analyses of the threat, in particular of the technical, tactical, and operational challenges posed by the opponent’s current and projected developments in fighter aircraft and air combat (I-A). The Soviet Union first very carefully analyzed the lessons of the Vietnam War, and came to the conclusion that maneuverability was the critical characteristic in future battles for air superiority. It did not, however, waste resources pursuing a variety of different technological paths to this tactical challenge. Instead, technical opportunities created by Soviet weapons laboratories were translated into operational requirements only when a very well-defined threat environment dictated that this course of action was appropriate (I-B, I-C) -- specifically, when the direct hardware threat to which a Soviet system would have to respond had been clearly identified. This strategy was dictated by the Soviets’ resource scarcity and its inability to afford travelling down technical paths which would prove unfruitful.
In the post-Cold War era, the Russian system of threat assessment and response is quite opposite of that during the Soviet period. The physical and cognitive resources no longer exist to carry out such detailed and precise threat assessments; in fact, many Russian analysts have admitted that very little is happening in terms of real formation of doctrine from which weapons designers and producers might draw guidance.

Instead, initial requirements-setting for Russian weapons systems is taking place along the same set of organizational dynamics that governed the design and development processes during the Soviet period, and now dictates the entire procurement time-line: organizations responding rationally to the incentives presented to them, and struggling to stay afloat given their chaotic environments. During the Cold War, Soviet weapons designers essentially refused to realize the requested technical specifications handed down to them by the armed services because their standard operating procedures (III-A) were dictated by other factors, most critically the gross output demands of central economic planning. These conservative, risk-minimizing organizational behaviors (III-A, III-E) included the ratchet effect, stockpiling of material supplies, and the lack of concern for cost-effectiveness, all of which mitigated against the design and production of technologically sophisticated aircraft and other weaponry.

The Soviet research institutes and design bureaus were
able to continue these behaviors with impunity because of their monopoly, or near-monopoly, on design and production capability; the armed service has nowhere else to turn to purchase necessary hardware. The armed services did not even enjoy power over resource allocation to the contractors; instead, those money and materials were doled out by the industrial ministries, which also had a stake in the gross output bottom line. Indeed, even the organizational innovation most directly intended to fight the quality control problem, the military representatives, fell victim to the design and production facilities' hold over resources, in this case the perquisites which determined so directly the Soviet workers' quality of life. None of these outcomes comes as a surprise when the resource dependency tenets of organization theory are taken into account; these theories predict that the more an actor in the weapons procurement process controls scarce resources, the more control he will have over weapons system choices and outcomes (III-C), and that the degree of power accruing from the holding of scarce resources will vary inversely with the number of alternative suppliers of those resources (III-D). In the case of the Soviet weapons designers and producers, their frequent monopoly power meant that they could call the shots at virtually every opportunity.

Of course, in the post-Cold War period, with resource allocations to defense research and production having been slashed so quickly, the tables have turned. Soviet, and now
Russian, organizations concerned with defense research, design, and production are now struggling to maintain any semblance of control over their core mission (III-B), now defined as being able to pay the wages of key personnel. They have adopted a variety of survival strategies in order to realize this goal, including haphazard attempts at conversion and struggles to find new customers and funding sources (preferably hard currency) under market conditions. As is the case with U.S. Air Force personnel desperate to save the F-22, Russian defense industry spokesmen are now trumpeting a continued threat from a probably exaggerated adversary (II-C) in order to get resources shifted back to their programs; it is interesting to note once again that, while the key organizational player in the United States cases was the armed service (the Air Force), in the Soviet/Russian cases the dominant players still seem to be the research and industrial organizations.

Indeed, the organizational coalition-building within the military research and industrial sector seems to shift depending on the goal being pursued. Naturally, the pressure of scarce resources is forcing these organizations to adapt through both competition and coalition-building (III-D). Competition within the sector stems from the advantageous position of the production facilities as opposed to the design bureaus and research institutes; the former are in better health because they produce a more immediately saleable
product and can therefore attract capital from non-governmental sources more readily. Naturally, the design and research facilities have argued strenuously to be allotted a share of those funds. These same competitors, however, manage to ally against a common adversary. For example, they have lobbied together to wrest authority to conclude arms export deals away from the government, so that they might share in the additional revenue. They have also entered coalitions to form military-industrial commodities exchanges and joint-stock organizations, once again entities designed to increase their mutual flow of capital. The defense industry research, design, and production facilities have drawn the line, however, at mergers. Their unique reputations and histories seem to preclude this option.

In addition to organizational dynamics, personal preferences and political skill also seems to have affected the design and production of Soviet (and now Russian) weapons systems, both during the Cold War period and even more so today. The political clout of particular engineers and their technological preferences, for example, played an enormous role in shaping the flight control and weapons control systems on the MiG-29, in keeping with bureaucratic politics models which emphasize the identification of individual personalities or factions with particular technologies and their incorporation into weapons systems (II-A). In the current Russian environment, the political skill of the head of a
research institute or design bureau can make or break his institute.

In relation to the discussion of Mikoyan’s and Sukhoy’s propensities to take technological and managerial risks, some interesting comparative observations can be made about the Sukhoy and Lockheed Skunk Works organizational environments. Unlike more "traditional" large organizations, which organization theory observes are inherently conservative and tend to adhere strongly to routine behaviors (III-A), the both of these weapons design institutions have adopted an organizational philosophy quite the opposite. Indeed, although to a lesser extent than its American counterpart, it is possible to characterize Sukhoy’s organizational essence as deliberately, inherently innovative, particular when compared to Mikoyan and the other Soviet design bureaus. The ability to take these risks most certainly had a critical impact on the resulting Sukhoy aircrafts’ eventual technical and tactical attributes, for example, the early incorporation of fly-by-wire into the Su-27.
Chapter Eight:
The Technonational Approach: Japan and the FS-X

Because Japan has felt secure throughout the post-war period in the security umbrella provided to it by the United States, its weapons design and procurement processes have responded to motivations other than threats and events in the international system. Indeed, the Japanese defense infrastructure seems to have developed only a very immature capability for realistic threat assessment. Instead, Japanese military industry outputs are the result of often well-coordinated attempts, throughout the requirements definition, design, and production process, to maximize benefits to domestic civilian industry and technological development. In other words, Japan follows a distinctly technonational approach to technology, national security, and weapons development. The FS-X is an excellent illustration of Japan’s attempts to use a weapons procurement program in order to further the development of a commercial aircraft industry.

The FS-X: The Initial Requirement

The first hints of a new Japanese fighter came in the mid-1970s, when Mitsubishi Heavy Industries (MHI) began to focus on a new aircraft after beginning full production of the F-1. By 1979, MHI had formed a project team to harness technologies from the coproduced F-104, F-4, and F-15, and the
indigenous T-2 and F-1.\textsuperscript{1} In late 1980 Mitsubishi announced its intention to develop an FS-X fighter to replace the F-1 close support aircraft. Mitsubishi was responding to a Japanese Defense Agency (JDA) requirement for a fighter-support aircraft that could be used "to prevent the enemy from landing in our country and to support our ground forces by attacking from the air the enemy units that have landed, with a secondary role as an air combat interceptor."\textsuperscript{2} The strategic rationale behind this requirement was military intelligence analysis which stressed a growing Soviet ability to invade the northernmost Japanese island, Hokkaido.\textsuperscript{3} The practical result was to justify a domestic aircraft by writing a requirement so unique as to virtually eliminate any existing plane from consideration -- Japan had decided that it was time to build its own aircraft.\textsuperscript{4}

As of 1980, about 70 F-1s were scheduled to be replaced starting in 1990, and Mitsubishi planned to begin FS-X

\textsuperscript{1} Michael J. Green, "Kokusanka: FSX and Japan's Search for Autonomous Defense Production," Massachusetts Institute of Technology Japan Program paper 90-09, Cambridge, MA, 1990, p. 43.

\textsuperscript{2} Cited in Otsuki Shinji, "Battle Over the FS-X Fighter: Who Won?" Japan Quarterly, April-June 1988, p. 139.


development in 1983 or 1984. Anticipated aircraft features included control-configured vehicle (CCV) technology for improved maneuverability and unconventional flight modes such as direct lift and side force control. The JASDF in late 1980 was also examining the alternative of modifying the F-1 to a CCV F-1X around 1990. Other FS-X requirements stemmed from the R&D projects the TRDI had pursued for years because it was denied U.S. technology in the F-15 co-production program -- basic airframe technologies, avionics, electronics, and materials. From the early 1980s, the TRDI and JDA helped Japanese industry to gain valuable systems integration experience through the production of the XT-4 trainer and the Service Life Extension Program on the F-4J.

In mid-1982, Japan listed seven different aircraft as possibilities for its next generation of support fighter:

* a modified McDonnell Douglas F-4EJ, manufactured under license by Mitsubishi Heavy Industries;

* a modified version of the F-1, also made in-country by Mitsubishi;

* the F-16XL produced by General Dynamics;

* the European Panavia Tornado;

* the British Aerospace Harrier;

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7 Green, 1990, pp. 43-44.

* Fairchild Industries' A-10; and
* the McDonnell Douglas F-15E Strike Eagle.

Most observers at the time were betting on the F-4EJ, which at the time was in the midst of a one-year test to determine whether its service life could be extended by 1,500 flight hours, and its central computer, fire control, radar navigation, and weapon systems upgraded. An ASDF spokesman commented that the F-1's "capability is not as good as the F-4EJ." The F-16XL and A-10 were hampered by their advanced ground attack capability, which could be construed as offensive in nature or having the potential for attack, thereby violating Japan's peace constitution. The European aircraft suffered the handicap of Japan's preference to gear its defense forces toward compatibility with the United States. It is likely, in fact, that the European planes were only included in the competition in order to convince Western Europe that Japan was at least considering their products, or perhaps to put some heat on the United States.

In 1983 the JASDF decided to carry out a service life extension program (SLEP) on the F-1. The F-1 SLEP was designed to enable the aircraft to remain in service for an extra 5-6 years beyond its originally 1990 retirement date. Introduction of 24 new close-support aircraft, now designated the SF-X and scheduled for purchase by 1987, was therefore postponed. Mitsubishi carried out an F-4J service life

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extension program (SLEP) in 1982 and 1983, increasing airframe life from 3,500 to 5,000 hours. About 100 of the 130 F-4Js in service were modified.\textsuperscript{10}

According to many observers, these SLEPS were clearly intended to give local industry time to develop an indigenous aircraft. If the original plan to put 24 SF-Xs into service as replacements for the F-1 before the end of 1987 had been realized, there would have been little time for domestic development, and foreign competitors would have had a good chance of being chosen.\textsuperscript{11}

Serious planning for the new fighter got under way in 1983 and 1984. Mitsubishi and other Japanese firms had been researching aerodynamics, materials, and electronics specific to future combat aircraft for several years. Industry was hoping in 1984 for the formal initiation of a national fighter development program, and was gaining support for such a project within the Japanese Defense Agency.\textsuperscript{12}

The JDA was at this time beginning to consider replacing part of the F-4EJ fleet as well as the entire F-1 fleet with the proposed new fighter. This would raise the number of replacement aircraft to 100-150, and expand their mission to


include both close support and interception roles. With initial operating capability (IOC) set for 1993, the planned 15-ton, twin-engined, twin-fin aircraft would incorporate CCV, composite construction, and stealth technologies, with a payload or more than 5,000 kg (11,023 lbs) and a 950-mile range (the distance from mainland Japan to Iwo Jima). Its speed would range from Mach 0.9 at low altitude to Mach 1.8 at high altitude, with a maximum speed of Mach 2.3 without external armament. The aircraft would carry two anti-ship missiles or as many as eight infrared and radar homing air-to-air missiles, guided by an advanced fire control system. Other equipment would consist of a phased-array radar, a 20-mm Vulcan cannon, and an ALQ-8 radar jamming device. The engine, ejection seat, and head-up displays would be imported. The proposed design of the plane had the main wing in the back, with canards in the front to substitute for horizontal tail planes. The canards and two vertical tail planes would be computer-controlled to give the aircraft excellent maneuverability. These specifications were impossible for any existing aircraft to meet, foreign or domestic. No evidence exists that the JDA ever carried out a legitimate threat.


assessment that resulted in these requirements.\textsuperscript{15}

The ASDF asked the Technical Research and Development Institute (TRDI) early in 1985 if Japan had the manufacturing capability for such an aircraft. The TRDI replied in the affirmative, with the caveat that the engines would have to be bought off-the-shelf from another country.\textsuperscript{16} Mitsubishi officials hoped to complete development for $85 million over a ten year period and hold the unit price of production aircraft to $34 million in 1984 dollars. This compared with 1984 costs of $46.8 million for an F-15J and $12.8 million for an F-1. JDA initially offered somewhat different estimates, with development costs around $800 million and production costs of $32 million if 100 aircraft were produced, and $28 million if 250 were built.\textsuperscript{17}

JDA's original development cost estimates were considered wildly optimistic by most observers. Rolf Riccius, marketing director of Panavia Aircraft, told reporters in July 1985 that his best guess was a total development price tag of closer to $2 billion. Panavia claimed that it could supply 100 Tornados off the shelf to Japan at around 40% of the cost of a Japanese FS-X program, with each aircraft priced at around $18 million. Licensed production of the Tornado would weigh in at around

\textsuperscript{15} Chinworth, 1992, p. 139.


\textsuperscript{17} Burton, 22 July 1985, p. 12.
65% of the cost of domestic FS-X development. McDonnell Douglas offered to sell the F-18 to Japan at $22 million a copy, based on a minimum buy of 75 aircraft. The JDA responded to these offers with its own recalculation of FS-X development costs, claiming a new figure of $600 million and a unit cost per aircraft of $20 million. This new estimate reflected lower cost estimates for engine assembly and electronic equipment. The JDA also argued that the Tornado, the F-18, and the F-16XL would be outdated by 1997, when full-scale development of the FS-X was scheduled to begin, but that the United States advanced tactical fighter (ATF) would not yet be ready. Japan therefore had no choice but to develop the FS-X itself.

Even at this early stage, some Japanese government officials, particularly from the Ministry of Finance, opposed indigenous development of the fighter because of cost concerns. Ministry of International Trade and Industry (MITI) officials also cautioned at this time that the United States might oppose a national development program, since it had been trying to sell the F-16 to Japan as an F-1 replacement. Several European trade delegations to Tokyo similarly argued that Japan’s purchase of European combat aircraft would be an ideal way to reduce Japan’s trade surplus with the European Economic Community. The United States at this point also

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registered concerns about interoperability with American forces if Japan produced its own fighter, although Japanese officials countered that these problems would be minimal as long as Japan used the same armament as American fighters.

Another argument dictating domestic development was the handwriting on the wall concerning U.S. technology transfer -- Japan's ally was getting tougher. Many more restrictions have been placed on the F-15J program, for example, than on the earlier F-4J coproduction; forty percent of the American F-15, primarily its most advanced components, went to Japan as "black boxes," and even then the U.S. Congress fretted that too much valuable technology was being transferred.20

Planning for the aircraft, now commonly referred to as the FS-X, was kept secret in these early stages, both to prevent its cancellation for budgetary reasons, and to keep foreign competitors on edge. At one point in mid-1985, the air staff office, acting on the advice of the JDA, "forgot" to affix its stamp acknowledging receipt of a report on FS-X development plans so that it could officially deny knowledge of the project's progress to Diet members.21

It is therefore not surprising that, after several months of examination of FS-X mission requirements and technical

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feasibility studies, the TRDI in September 1985 recommended domestic development and production of Japan's next fighter.\textsuperscript{22} Indigenous development was formally codified in the Japanese cabinet's Mid-Term Defense Plan of 1985.\textsuperscript{23} The plan called for 100 aircraft to replace the 69 F-1s then in service, and left the door open to use the aircraft also to replace the F-4EJs, which would mean increasing the procurement to 200-205 planes and combining support and interceptor missions in the aircraft. The anti-ship support mission would be primary, and therefore the FS-X would need sufficient range to carry out patrols over Japan's sea lanes. Mitsubishi Heavy Industries was selected as the prime contractor.\textsuperscript{24}

Despite TRDI's recommendation, the JDA in November of 1985 sent requests for performance specifications and price quotations to three non-Japanese aircraft firms -- McDonnell Douglas (F-18), General Dynamics (F-16), and Panavia (Tornado).\textsuperscript{25} The prices included procurement on both an off-the-shelf and licensed production basis. Of the three foreign

\textsuperscript{22} See "Japan Sets Fighter Weight," \textit{Flight International}, 7 September 1985, p. 12.


aircraft, the F-18 was considered the leading candidate; the choice of a European aircraft was seen as unlikely, and Japan's preference for a twin-engine aircraft weighed against the F-16. Operational safety over the ocean was the stated reason for the reluctance to consider a single-engine aircraft, although insiders indicated that the JDA was also worried about crashes over civilian residential areas. 26 At this point, Kazuo Fujii, defense counselor of the JDA, insisted that neither domestic production benefits nor trade problems with the United States would influence the final decision. "We will decide after strictly considering cost effectiveness." 27

Nevertheless, most U.S. defense industry sources at the time were quite pessimistic about their chances. One U.S. contractor said that a senior JDA official told him that all the key departments of the JDA plus the ASDF Air Staff Office favored domestic development. One American involved in the process later recalled, "They didn't want to hear about the capabilities of the new versions of the U.S. planes. They were bent on building their own plane and only wanted to hear that existing U.S. models did not meet their requirements. They closed their ears to anything else." 28 In fact, U.S.

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28 Gregg Rubenstein, quoted in Prestowitz, 1989, p. 18.
industry sources feared that the information acquired on foreign aircraft through the November 1985 request might simply be used to help Japan in its domestic development of the FS-X.  

Co-development Becomes an Option

Gregg Rubenstein, then deputy director of the Mutual Defense Assistance Office in Tokyo, first raised the possibility that indigenous Japanese development of the FS-X would not serve U.S. security interests in a cable he sent to Washington in October 1985. He argued that simple co-production of an existing American aircraft would not be acceptable to Japan, but that the Japanese would get an inferior aircraft if they tried to go it alone. The latter option also, of course, would shut the United States out of the program altogether, risking a loss of business for American firms and a potential challenge to U.S. predominance in the international commercial aircraft market. Rubenstein was therefore the first to suggest the co-development option, with the United States and Japan collaborating in both the development and production phases. In this way, he argued,


30 See Spar, 1993, pp. 72-73.

31 Other prominent observers at the time agreed: "There is no way in hell they're going to buy the plane right off the shelf." Michael Chinworth, quoted in Bruce Stokes, "Beat 'Em or Join 'Em," National Journal, 25 February 1989, p. 461.
Japan could still benefit from the technical experience and national symbolism it was after, and the United States' fears about interoperability and Japanese technological autonomy would be assuaged. By late 1985, co-development had become the Pentagon's official preference for the FS-X.

Into the spring of 1986, Japan narrowed the list of foreign contenders to a twin-engine vehicle, effectively eliminating the F-16. The F-18 appeared to be a front-runner against the Tornado, although in addition to concern that the F-18 would be 20 years old by 1997, many observers doubted that the McDonnell Douglas aircraft would meet specific Japanese design requirements. According to one JDA engineer:

The Air Self-Defense Force requirement calls for a 450-nautical-mile radius in lo-lo-lo-hi antishipping mission with six missiles, including four Mitsubishi Type 80 (ASM-1) air-to-ship missiles. The requirement also calls for a mission role with either air-to-air missiles, including four semiactive radar homing medium-range and infrared homing short-range weapons for an air combat mission. It is doubtful whether the current version of the F-18 can fill the 450-nautical-mile radius requirement with the four 13-ft. long missiles and their 1,320-lb weights.\(^{32}\)

Meanwhile, enthusiasm in Japan for a domestic development program was running high. MITI and Japanese industry were confident of their development capability; they also supported indigenous development because the FS-X would probably be the only chance to carry out a fighter development project for the

next 25 years. It was widely believed that, after the FS-X, the next interceptor project, the FX replacement for the F-15J, would be the same model as the U.S. Air Force's Advanced Tactical Fighter. One Society of Japanese Aerospace Companies (SJAC) official painted the situation in terms of the future of the domestic aerospace industry: "If we are not given the opportunity to carry out the FSX program now, another such development program is not expected to 20 or 30 years." In his words, the government should not extinguish "the torch of hope" for the defense industry by allowing foreign development of the FS-X.33 Itsuro Masuda, FS-X program manager for Mitsubishi Heavy Industries, was even more direct: "Abandon all this [the indigenous work already carried out on FS-X]? Unthinkable. It would be criminal to lose the last chance of allowing the Japanese aerospace industry to make up lost ground."34 Only the Ministry of Foreign Affairs continued to object to domestic development, arguing that the FS-X requirement was being written deliberately to eliminate foreign aircraft.35 The MFA was concerned about revising the trade imbalance with the United States and with saving development money.


Mitsubishi Heavy Industries, in conjunction with TRDI, led the industry-wide effort to develop technologies relevant to the FS-X. Key programs included supersonic aerodynamic research, application of fly-by-wire and CCV technologies, low radar observable (stealth) technologies, composite materials for primary structures, and airborne phased array radar an advanced central computer system. Japanese engineers expressed confidence that the system could be completed in ten years; this optimism was evidently based on favorable results with the Kawasaki XT-4 intermediate trainer aircraft, on which many domestic companies worked to complete a design that met its specification in flight testing.36


Three manufacturers competed for the engine contract: General Electric's F404-F2J1, Pratt & Whitney's PW1120, and Rolls Royce's RB 199-34. There was some early concern that the Reagan administration would bar the GE and Pratt & Whitney designs on the grounds that too much critical high technology would be transferred. The engine was to be produced under license in Japan by Ishikawajima-Harima Heavy Industries.37

37 "Japan Near Decision," 10 March 1985, p. 89.
In late 1985, the United States proposed a cooperation project for the FS-X based on an upgraded F-18, a Super Hornet, which would introduce CCV and stealth technologies and make other changes to meet Japanese mission requirements.\(^{38}\) Initially, the Super Hornet concept was intended for licensed production, but it later evolved into a co-development plan. The American F-18 procurement program was suffering from structural problems, and U.S. officials were pleased at the prospect that its deficiencies would be corrected at Japan's expense.\(^{39}\) The addition of Japanese electronics to the aircraft would also improve its performance considerably. General Dynamics also briefed the Japanese government's Aviation Staff in October 1986 on similar proposals for an upgraded twin-engined version of the F-16XL, featuring a "cranked arrow" wing, a longer fuselage and improved systems technologies.\(^{40}\)

The U.S. apparently hoped that currency exchange rate trends would influence Japan's decision in favor of an American aircraft; the value of the yen had increased rapidly from the beginning of 1986, and Japan's estimated trade advantage with the United States soared to about $70-80

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38 These changes included uprating the engines to 8000-9000 kg, adding a dorsal bulge to take extra fuel, improving the radar, and adding provisions for three 1820 liter external fuel tanks. See Braybrook, June 1987, p. 60.


billion. Late in 1986, it became clear that the economics of the situation, which make the price of U.S. products considerably cheaper, were making co-development seem like a more attractive option to Japan, particularly given limits on overall Japanese defense spending.\footnote{Paul Bedard, "U.S. Firms Seen in FSX Role," Defense Week, 2 September 1986, pp. 1, 13.} Co-development was a compromise between the interests of Japanese firms, which wanted to exclude American aerospace companies altogether, and U.S. firms, which wanted Japan to buy an American jet. The pressure of beneficial exchange rates prompted Mitsubishi in late 1986 to step up its lobbying efforts to keep the FS-X an all-Japanese product.

When General Dynamics and McDonnell Douglas went to Tokyo in October 1986 to make final presentations on their respective proposals, the JDA handed them an additional list of detailed specifications. These included requirements such as the capability to take off in 110-degree heat; as pointed out by one science policy expert on the U.S. Senate staff, it has only hit 110 degrees once in the last century in Japan.\footnote{Ed McGaffigan, Senate staffer, quoted in Martin and Susan J. Tolchin, Selling Our Security, Penguin Books, New York, 1992, p. 89.} Other specifications included fast takeoff, extended range, and canopy protection against bird strikes. John Tyler, one of the Defense Security Assistance Agency negotiators, remarked about the latter in particular.
They wanted to be able to take a bird strike -- a big bird -- at high speed, so that the cockpit would not shatter...They hadn't done their research on bird size and frequencies, and they certainly hadn't done the proper research on what happens when you build the glass that thick -- you get distortions. We took a team over and demonstrated all this, showing why it was such a bad idea. They considered that extremely threatening, the fact that we were chipping away at the credibility of their own experts; they didn't like that, the fact that we were focusing on real knowledge and real expertise.\textsuperscript{43}

To no one's surprise, American officials were told that the F-18 and F-16 upgrades did not meet the new requirements. A joint team from the two contractors and the Pentagon returned to Tokyo six months later to resubmit their aircraft based on the amended specifications.\textsuperscript{44}

In March of 1987, a consortium of five Japanese defense contractors -- Mitsubishi Heavy Industries, Mitsubishi Electric, Kawasaki Heavy Industries, Fuji Heavy Industries, and Ishikawajima-Harima Heavy Industries -- submitted their plans for developing the FS-X to the JDA. A decision had to be made by August of that year, in time for the necessary and appropriate funds to be written into the following fiscal year's budget.\textsuperscript{45} As the summer drew near, it became clear that the decision would be for domestic development. Although the JDA privately was admitting that the Super Hornet would

\textsuperscript{43} Quoted in Tolchin, 1992, p. 97.

\textsuperscript{44} "Battling For Japan's New Fighter," Defense Week, 6 April 1987, p. 16.

\textsuperscript{45} "Fight Over Fighters?" The Economist, 7 March 1987, p. 72.
meet the new requirements, General Dynamics and McDonnell Douglas both hinted that those requirements would entail such large-scale retrofits and performance improvements to their aircraft that the final projected costs would exceed the limits set by the JDA.

In April 1987, a U.S. technical team sent to Japan (the "Sullivan mission," named for its head, Assistant Deputy Undersecretary of Defense Gerald Sullivan) concluded that any one of four American aircraft could meet the JDA’s mission requirements better and more cheaply than the Japanese alternative. American officials on this trip reported that Japan’s insistence on domestic development of the FS-X had much more to do with industrial goals than on military requirements. In fact, mission representatives explained to their Japanese counterparts, the FS-X requirements were all wrong, if they were really intended to meet tactical and strategic goals. The Sullivan team agreed with the basic

46 The new requirement was what one observer characterized as a canard derivative of the F/A-18, with the wing and vertical tails moved further aft, the intake ducts stretched forward, ending in vigilante-type inlets, and the horizontal tail surfaces replaced by foreplanes mounted on top of the intakes. The wing was still mid-set, so the foreplanes were given a large dihedral angle to place them high enough above the wing-plane for favorable interference. The very small sweep angle of the F-18 was retained, but the flaps were enlarged and the ailerons deleted, with roll control apparently provided by the foreplane. See Roy Braybrook, "Decision Time for Japan’s FS-X," Pacific Defence Reporter, June 1987, p. 59.


mission of securing the Soya Strait between Sakhalin and Hokkaido by using the FS-X to attack Soviet missile firing and troop-carrying ships. The Japanese, however, set the tactical parameters intended to accomplish this mission in a very different way than the Americans would have conceived them. The JDA focused on attacking ships once they had breached Japan’s twelve-mile sea limit, and planned to load the FS-X with maximum weaponry and fuel for this anti-ship role; the U.S. would have preferred to plan to strike at a greater distance, and focus more heavily on the possibility of the aircraft’s having to perform the secondary roles of dogfighting with Soviet MiG-29s. The Sullivan team tried to convince the Japanese that their current FS-X requirement was overemphasizing some tactical roles and ignoring several critical others.49 In fact, Sullivan became convinced that the Japanese Air Self Defense Forces had not engaged its sister services, the naval and ground forces, in discussions on coordination of combat activities and the proposed mission of the FS-X. One high Ministry of Foreign Affairs official explained the situation as one in which the JDA had no strategy and was governed by business and the fear that if it missed this chance Japanese technology would be lost. The United States already defended Japan with its F-16s based in Misawa, went Japan’s thinking; those American aircraft

performed the mission for which the FS-X was ostensibly designed. Why should Japanese industry dwell on duplicating an already-covered mission?\(^{50}\)

The Pentagon, convinced by the Sullivan mission that Japan was not serious about defining its combat aircraft to real tactical requirements, made a decision to tighten its negotiating posture. In June 1987, Richard L. Armitage, the assistant secretary of defense for international security affairs, told Seiki Nishihiro, the top career official in the JDA, that the United States would accept neither domestic development nor coproduction.\(^{51}\) Instead, the new Japanese fighter would have to be co-developed, and based on an existing American model. Caspar Weinberger insisted to the Japanese defense minister that the FS-X issue "went to the heart of the U.S.-Japan relationship."\(^{52}\)

The situation became even more complicated in June 1987, when McDonnell Douglas entered an F-15 derivative into the discussion. The F-15 had been ruled out at the beginning of the competition because of its high cost, but with exchange rates reducing its unit price by nearly 25%, the company apparently thought it might have a chance. The F-15 presented an attractive option because of its ability to perform an interceptor as well as close air support role. Its entry

\(^{50}\) Prestowitz, 1989, p. 28.

\(^{51}\) Spar, 1993, p. 77.

\(^{52}\) Prestowitz, 1989, p. 29.
"captured center stage" along with the indigenous Japanese design because of the JDA leadership’s regard for the aircraft as superior to the F-16 and F-18.\(^{53}\)

With this new element in the equation, Japanese Defense Minister Yuko Kurihara agreed to meet in Tokyo in late June with U.S. Defense Secretary Caspar Weinberger, and to postpone a final decision until later in the year. This meant that the funding request would have to be included in Japan’s Fiscal Year 1988 budget without a selection having been made, a highly unusual move, but considered appropriate because of the complexity of the situation. A secondary reason for the delay may have been a power struggle then taking place within Japan’s ruling Liberal Democratic Party, diverting most politicians’ attentions away from military issues. The election of a new Prime Minister in October resolved this conflict, putting the FS-X high on the agenda once again.

Throughout the summer of 1987, Japanese aerospace industry officials toured U.S. aircraft development facilities, gathering data on the feasibility of all the proposed options. Off the record, however, Japanese industry officials made it clear that their strong preference was for domestic development. One Mitsubishi official was quoted as saying, "This is a matter of defense, so domestic development is the first priority and joint development under Japan’s

control is second best. Using the FSX as a way to mitigate U.S. criticism of Japan's trade surplus is out of the question.54 As was the case previously, many U.S. officials sensed that the Japanese were using these trips not so much to consider seriously the purchase of American aircraft as to capitalize as much as possible on American technology for their own development program.55

At the end of August, General Dynamics, motivated by cost concerns, formally withdrew its offer to develop a twin-engine version of the F-16 for the FS-X program.56 Upset by this move, Japanese officials hinted that they might buy an off-the-shelf U.S. aircraft as an interim measure, primarily to placate the U.S. on trade issues, and postpone development and production of the FS-X until some unspecified time in the future.

Mitsubishi, still actively lobbying for a domestic development decision, spent the summer and fall of 1987 trying to convince the Japanese government that it was possible to develop and produce the aircraft at home at a competitive price. The company, first of all, developed a sophisticated system of cost control which involved breaking the aircraft


down in two ways: by segments, such as mid-fuselage or wing, and by function, such as structure or hydraulic system.\textsuperscript{57} A matrix was then constructed to display the developmental path of both the segmental and functional systems. Cost estimates were laid out for each point on the matrix where the two developmental paths cross, allowing the comparison of actual costs with predicted costs and system redesign as appropriate. The program manager also could know, with a quick look at the matrix, what the actual cost of the program is at each stage of development, and move quickly to control any costs that exceed established limits.

Mitsubishi also expanded the use of computational aerodynamics in order to demonstrate cost reductions.\textsuperscript{58} In particular, the company developed a computer-aided design (CAD) system that can accurately predict wing characteristics, even in a design that has a canard surface immediately adjacent to the wing. Wind tunnel testing produces the same data at ten times the cost, and takes a much longer time to complete a cycle of aerodynamic design. Finally, Mitsubishi argued that its use of technologies in which Japan has an advantage would give the FS-X more advanced capabilities and a longer service life. The developmental


\textsuperscript{58} Brown, 21 September 1987, p. 48.
program focused on:

* Advanced composites, which offer a weight advantage of as much as 40% over metal structures, but cost about the same. Mitsubishi had advanced programs in composite structure development and manufacturing, and had fabricated major structural test components for the FS-X.

* Stealth technology, both in the form of computer codes to help develop radar cross-section calculations and radar-absorbing materials. Test work was under way in a specially designed RF anechoic chamber at Mitsubishi's Komaki South factory. Work in the development of advanced RAM was being done by several Japanese companies in cooperation with Mitsubishi, with whom they had negotiated nondisclosure agreements. By blending these tow methods, Mitsubishi anticipated achieving the lowest-cost solution to the need for stealth capability for the FS-X.

* Advanced metallurgical processes, including superplastic forming and diffusion bonding. These processes were seen as helping control costs by reducing the number of parts that had to be fabricated. Initial work centered on superplastic forming and diffusion bonding of titanium and extended to aluminum. Mitsubishi was also looking at the advantages and disadvantages of the use of lithium aluminum in combat aircraft.

* Control-configured vehicle technology, including both direct lift and side-force control capabilities and integrated flight and fire control system technologies. Much of this work stemmed from the Mitsubishi T-2 CCV program, conducted from 1979 through 1983. One of the factors determined during this program was the effectiveness of direct lift and side-force controls in the final stages of air-to-air and air-to-ground attacks. These capabilities and the integrated flight and fire control system were expected to be integrated into the FS-X design.

* Integrated cockpit designs and integrated information display systems. Mitsubishi used an integrated cockpit model to evaluate its designs in terms of pilot-machine interface. The Mitsubishi cockpit was studies by the U.S. Department of Defense.

* Voice recognition techniques and associated command and control systems. Mitsubishi anticipated that it would

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59 Brown, 21 September 1987, pp. 48-49.
use a voice recognition and command system initially for display mode selection, and worked to develop a voice system that would work satisfactorily in the high ambient noise level of the cockpit.

* Advanced hybrid navigation systems, combining global positioning system and inertial navigation technologies.

* Advanced fiber-optic systems, including a fiber-optic data bus system. Mitsubishi developed a star-coupled data bus configuration using multichannel fiber-optic connectors.

* Active phased-array radar technologies, with equal air-to-ground and air-to-air capabilities. Developed by Mitsubishi Electric, this radar used a phased-array beam shifter that could be used both for air-to-air and air-to-ground work, and could shift rapidly from one mode to the other.

The United States' "buy American" arguments, and the trade and political issues behind them, acquired more force with the revelation that the Toshiba Machine Corporation, a subsidiary of the Toshiba Corporation, had illegally sold submarine-quieting propeller milling machinery to the Soviet Union. The incident dramatically increased criticism of Japan in the United States, and decreased Japan's leverage against the United States in trade and other areas.

The Selection of the F-16

Despite Japanese industrial lobbying, the JDA agreed in October 1987 to shelve domestic development of the FS-X, opting to co-develop a new version of either the F-15 or F-16

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instead. 61 Japanese Defense Minister Yuko Kurihara stressed, however, that Japanese industry would retain a leadership role in any co-development project, and that the selected airframe would be fitted with indigenous equipment, including a phased-array radar, an advanced fire-control system, and stealth technologies. In his words, "From the point of view of Japan's national interest, this was a difficult decision to make, and it represented a substantial concession on our part." 62 Clearly the decision was made solely to preserve the alliance with the United States. Kurihara explained: "Japan gave up the idea of domestic development of the FSX because we thought a decision aimed at maintaining good relations with the U.S. based on the Japan-U.S. Security Treaty was important." 63

The F-18 was eliminated from the selection list, despite Japanese industrialists' attitudes that it was the best platform for the FS-X, because of concerns about high development costs. 64 The F-15 modification (at an estimated development cost of $715 million) seemed the easiest solution, since the Japanese already coproduced the F-15J. Japan's

61 "Under Your Wings," The Economist, 10 October 1987, p. 36.

62 Quoted in Spar, 1993, p. 79.

63 Quoted in Spar, p. 79.

64 The F-18 modifications required to meet Japanese requirements would have cost about $1.86 billion, $428 million more than the JDA had budgeted for the FS-X. See "Japanese To Codevelop U.S. Aircraft Derivative for FS-X," Aviation Week and Space Technology, 12 October 1987, p. 34.
willingness to reconsider the F-16 came as a surprise, since General Dynamics had taken the twin-engine version off the table. Apparently the twin-engine requirement, along with many of the other specifications Japan had imposed throughout the development debate, was not absolute. The F-16 model under consideration, a single-engine version known as the SX-3, would employ advanced technology composite materials in all three fuselage sections.\textsuperscript{65}

Finally, at the end of October 1987, the JDA selected the General Dynamics F-16 as the basis for co-development of the FS-X, planning to build 130 of the aircraft to be deployed beginning in 1997. The FS-X design included a larger wing than the F-16, radar absorbent materials on the leading edge flaps, an extended nose section, forward canards, and the extensive use of composite materials. The larger nose, fuselage, and wing were needed to allow for carrying antiship missiles and more fuel for longer mission.\textsuperscript{66} Because of the single-engine configuration, the JDA asked for an increased thrust engine to power the FS-X, either the General Electric F110-GE-129 or the Pratt & Whitney F100-PW-1129.\textsuperscript{67} With this design, the FS-X was to have a top speed of Mach 2, a maximum payload of 22,000 lbs, and a maximum range of 516 stat. miles

\textsuperscript{65} "Japanese To Codevelop," 12 October 1987, p. 34.

\textsuperscript{66} Ortmayer, 1992, p. 2.

\textsuperscript{67} "Japan's Defense Agency Selects F-16 As Basis for FS-X Aircraft," Aviation Week and Space Technology, 26 October 1987, p. 22.
with four Mitsubishi-type 80 air-to-surface missiles. The first prototype was scheduled to fly in 1993.

Apparently the F-16's safety record and costs were primary consideration in Japan's choice of the F-16. Development costs for the F-15 derivative were estimated to be $1.5 billion, with a unit price per aircraft of $63 million. The F-16 is a bargain by comparison: $1.1 billion in development costs, with a unit price of $35 million per copy. The F-15, given its wide radius of action and tremendous offensive capability, might have caused political problems in Japan by seeming to overstep its defense-only military policy.\(^6\) Another consideration may have been that the F-16 offered greater possibilities in terms of stealth technology than its competitors.\(^6\) One Pentagon source also said that the plane has "more potential for growth" in adding Japanese components, such as Japanese-developed radar, avionics, and airframe composites; it left plenty of room for what would essentially later become Japanese development of an combat aircraft.\(^7\) Finally, it was suggested that Mitsubishi had already worked extensively with McDonnell Douglas on the F-15 co-production, and wanted to see what new it could learn from a different U.S. manufacturer; in addition, many observers

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\(^6\) Shinji, April-June 1988, p. 143.


\(^7\) Rowan Scarborough, "The Winner and Still Champion," Defense Week, 26 October 1987, p. 13; see also Prestowitz, 1989, p. 31.
have speculated that the JDA and Japanese industry were far from satisfied with McDonnell Douglas’ track record as a partner.\textsuperscript{71} The JDA may even have hoped that MHI would gain access to Advanced Tactical Fighter technologies by working with General Dynamics, one of the U.S. aircraft’s winning team members.

Throughout late 1987 and 1988, U.S. and Japanese government and corporate officials hammered out the draft memorandum of agreement to develop jointly the FS-X. The work split had U.S. companies receiving at least 35% of the development work on the project, with Mitsubishi Heavy Industries acting as prime contractor in Japan and General Dynamics as a principal subcontractor. Mitsubishi, as prime contractor, is responsible for portions of the airframe, avionics, digital flight controls, support equipment, and overall systems integration. General Dynamics is participating in the design and development of the composite wing box (the stationary portion of the wing), the aft fuselage, leading edge flaps, avionics test equipment, and stores management systems. Other prominent Japanese participants include the subcontractors Fuji Heavy Industries, which is responsible for developing the aircraft’s nose, composite wing upper skin, and tail assembly, and Kawasaki

\textsuperscript{71} Chinworth, 1992, p. 147.
Heavy Industries, which is developing the center fuselage. U.S. Defense Secretary Frank Carlucci and Japanese Defense Minister Tsutomu Kawara agreed that the U.S. would participate in the FS-X program from initial development through the completion of flight testing in 1996. The first prototype was slated for completion in 1993, with delivery of the first production aircraft in the fall of 1997 and a total run of 130 aircraft by 2001. In addition, it was agreed that Japanese technologies involved in the fighter program would be transferable to the United States, with no fees involved for the transfer of items that represent mere refinements of existing F-16 technologies. The U.S. would, however, have to request and pay for new technologies developed by the Japanese specifically for the FS-X via a "flowback" clause in the agreement. A joint engineering committee, including participants from the Japanese Air Self Defense Force and the U.S Air Force, was also to be formed to exchange technical information on the program. The final memorandum of understanding (MOU) for the aircraft development was signed in Tokyo between Japanese Foreign Minister Sosuke Uno and U.S.

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Ambassador Mike Mansfield on 29 November 1988.\textsuperscript{74} Details on actual co-production arrangements were not due to be discussed until around 1993.

Several development issues, however, remained unresolved. The major point of contention was the work share on development of the aircraft's single-piece, composite wings. General Dynamics wanted part of the design work. As one company official put it, "It's a new and interesting technology and naturally we are interested."\textsuperscript{75} In particular, General Dynamics was anxious to incorporate the new wing into its latest F-16 upgrade; it also recognized that the advanced materials technology might have applications for the Advanced Tactical Fighter contract, for which the company was competing. Japanese officials, however, insisted that all work on the innovative wings, which are the product of Japanese-funded development work, should be performed in Japan. By the end of January 1989, a classified agreement on the wings reportedly allowed General Dynamics to build two of the six total wing sets needed for testing and prototype construction, one to be earmarked for one of the four flying prototypes, and one for static testing, involving wind tunnel trials and ground-based stress tests for metal fatigue. The

\textsuperscript{74} "USA, Japan Sign Fighter Agreement," Jane's Defence Weekly, 10 December 1988, p. 1444.

remaining four wing sets were to be built by the Japanese --
three for flying prototypes, and one for static testing. In
addition, it was rumored that the Japanese would build a
seventh spare wing set in case one of the other sets was not
delivered on time or failed static testing. Mitsubishi
reportedly also agreed to allow General Dynamics technicians
to work in its Nagoya factories, where the FS-X wings were to
be built, to gain knowledge of Japanese composites
technology.⁷⁶ In particular, the American firm wanted to see
how Japan builds the wings using a co-curing technique that
allows the curing and bonding of composite parts in an
autoclave at the same time. "We co-cure some items," said
Vernon Lee, then vice president-Japan for General Dynamics'
Fort Worth Division and project program director. "What is
different is that no one has successfully co-cured a large,
highly loaded complex piece of structure like a wing."⁷⁷
General Dynamics was also to build the prototypes' aft
fuselages, and to play a role in avionics integration.

Japan’s Motivations: Technology and Systems Integration
Experience

In February 1989, a substantial monkey wrench was thrown
into Japanese FS-X development plans. U.S. Commerce Secretary

⁷⁶ John Boatman, "Japan/USA Reach FS-X Agreement," Jane’s

⁷⁷ Carole A. Shifrin, "General Dynamics Expects to Receive 75% Of U.S. Share of FS-X Development Work," Aviation Week and Space
Technology, 8 May 1989, p. 16.
Robert Mosbacher convinced the National Security Council that Japan was using the FS-X project as a springboard for an indigenous military and civilian aerospace industry that would eventually compete head-to-head with the United States; the Bush Administration therefore delayed by 60 to 90 days the decision to share F-16 technology, pending a more specific version of the licensing and technical assistance agreement between Mitsubishi and General Dynamics. 78 Because of the lack of a strong hand in the Pentagon, with John Tower's nomination for Secretary of Defense being delayed in the Congress, the Department of Commerce was able to wield a stronger hand on the FS-X issue than it might have under circumstances. 79 Other concerns included protection of sensitive U.S. technology, guaranteeing U.S. industrial participation beyond the development stage, and ensuring U.S. access to and transfer of Japanese technology.

Proponents of the deal argued that the codevelopment deal was actually better than the alternative, which was completely indigenous Japanese development, since General Dynamics would at least share in Japanese technological advances in avionics and co-cured composite structures. They also observed that it was only reasonable, given its economic situation, for Japan to respond to American demands to share the defense burden.


more equitably. The Pentagon in particular argued that the concern over Japan "spinning off" FS-X technologies was misplaced, as military and civilian aerospace designs are completely, in most senses even qualitatively, different.\textsuperscript{80}

Critics countered that Japan was simply out to gain access to as much U.S. technology as possible, and that indeed, the choice of the F-16 was made only because Japanese industry already had insight into McDonnell Douglas manufacturing processes through the F-15J coproduction. In particular, concern focused on Japanese access to source codes for the F-16's central computer.

The primary skill Japanese firms probably wanted to acquire from the United States through the FS-X co-development program is systems integration experience.\textsuperscript{81} As Richard Samuels and Benjamin Whipple have pointed out, systems integration is not only narrowly defined as the last link in the design and production chain in which all the various component parts and subsystems are fitted together into a functioning unit, it can also be used as a metaphor for the management process as a whole. "One cannot easily integrate subsystems at the tail end if the interface was not properly specified up front or if inevitable in-process design changes

\textsuperscript{80} Ortmayer, 1992, p. 6.

have not been properly managed." Since large aircraft systems are few and far between, and because their technical challenges are so many and complex, systems integration may be the most difficult aspect of aerospace design and production. Japan's defense industry strategy over the years clearly had been to begin with off-the-shelf purchases, then licensed production primarily involving insertion of indigenously developed components into empty "slots" in foreign systems, and finally domestic development. The last step is particularly difficult given the Japanese method of dividing design and production contracts virtually equally among three or four major firms. It can be difficult for firms to communicate throughout the design and development process, so that each manufacturer develops its own "piece" of the aircraft separately, leading to inevitable integration difficulties down the line.  

The F-4J Service Life Extension Program (SLEP), according to several accounts, was an attempt to provide Japanese manufacturers with valuable systems integration experience, a kind of "test run" to prove that they could handle the larger, more important challenge of indigenous FS-X development. For the F-4J SLEP, Mitsubishi Heavy Industries essentially completely rebuilt the aircraft, installing and integrating a completely new, albeit mostly American, avionics suite. This

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82 Samuels and Whipple, p. 10.
83 Interviews.
program still did not, however, provide Japanese industry with the experience of completely designing and building its own aircraft from scratch.

The JDA gave industry that opportunity with the supersonic XT-4 trainer. A trainer is a good trial program for gaining systems integration experience, since its technologies and integration demands are less demanding and complex than those in a full-fledged fighter. Kawasaki Heavy Industries took 40% of the XT-4 production contract, with Mitsubishi and Fuji Heavy Industries evenly splitting the other 60 percent. Samuels and Whipple describe the experience:

The challenge of XT-4 development was more managerial than technical, as it replicated in miniature all aspects of an FS-X program, but with less demanding technology. A tight schedule, small budget, and almost equal participation by the three major firms intensified the demand for skillful management at every link in the value-added chain. Despite their inexperience, Japanese managers proved their ability to meet these demands when the first plane rolled out a month early and on budget, an exceedingly rare event in aerospace. Equally unusual, the XT-4 reportedly met all specifications during flight testing and entered production on schedule in 1986. The complete success of the project contributed greatly to the increasing self-confidence and domestic credibility of the Japanese aerospace community, leading one U.S. official at the time to note "peacock-like tails over Mitsubishi and the others."

Indeed, Ryozo Tsutsui, who initially directed Japanese FS-X development, commented that he was quite gratified by the success of the XT-4, and that he placed high confidence in the

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84 Samuels and Whipple, pp. 19-20.
85 Samuels and Whipple, p. 20.
current state of Japanese aerospace technology.\textsuperscript{86}

In addition to concerns about Japan gaining systems integration experience which might transform it into a formidable competitor to the United States in commercial aircraft markets, critics of the FS-X program also worried about the imprecise wording of the MOU, which leaves specification of U.S. work share once production begins until well into the development phase. A General Dynamics official was not concerned: "It’s understood that General Dynamics will gain a share of the production contract, comparable to the 35-45\% it will have in the development phase." But Congressional sources had doubts. One staffer commented, "That’s an out for [the Japanese] to say that General Dynamics won’t be compatible with Japan’s production."\textsuperscript{87} Senator Jesse Helms insisted that Japan buy 50-60 F-16s off the shelf before FS-X co-development would begin.

Japanese officials were not pleased with this turn of events. A senior Mitsubishi official summed his country’s frustration with his complaint that the U.S. had forced the F-16 on Japan in the first place, even though the JDA had felt that the aircraft’s 1970s technology was outdated and therefore suboptimal. "We have to change more than 70\% of the


\textsuperscript{87} Quoted in Mecham, 20 February 1989, p. 17.
F-16 design to meet the agency's requirements."

Many Japanese negotiators quoted another official, "To buy an F-16 off the shelf would be like marrying a middle-aged lady when you are young." Indeed, a number of Japanese defense and industry officials clearly hoped the deal would fall through so that they could go back to their original plans for indigenous development. One particularly disturbing theme that emerged in the Japanese debate was a sense that American technology was no longer a reliable base on which to build a Japanese aircraft. As one editorial writer for a major Japanese daily commented, "There is less confidence now in U.S. technology; there is a feeling among the Japanese that the U.S. could not make the next generation of jets. Where the U.S. cannot fulfill its role, the Japanese Defense Agency will increase its role. This trend will continue as we enter the 1990s."

Most American observers doubted that Japan could design and produce a modern fighter without substantial U.S. support, citing the non-innovative character of the Mitsubishi F-1.

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88 Mecham, 20 February 1989, p. 17.

89 Toshinori Shigeie, director of the National Security Affairs Division, North American Affairs Bureau, Ministry of Foreign Affairs, quoted in Tolchin, 1992, p. 82.


91 Kiyofuku Chuma, writing for the Asahi Shimbun, quoted in Tolchin, 1992, p. 81.
They countered the Japanese officials' pithy comments with their own: "Why should you climb Mt. Fuji alone when you could start with a partner halfway up?" Many questioned Japanese claims of technological superiority in focal plane arrays, co-cured composites, and radar system miniaturization; they also insisted that Japan needed General Dynamics' skills in systems integration.

President Bush heard over two hours of widely conflicting views on the FS-X situation at a National Security Council meeting on 15 March 1989. By the meeting's end, it was apparent that the final decision would be his. Technically, Bush had until the end of March to make a decision; the $80 million earmarked for FS-X development funds in Japan's 1988 budget had to be spoken for by that date, the end of Japan's fiscal year. Ultimately Bush approved the co-development, but only with Japan agreeing to a 40% share of the FS-X production contract. It was highly unusual for Japan to make production guarantees at such an early stage. Bush also insisted that the amended MOU contain written assurances that Japan would transfer advanced technology it developed for the fighter to the United States, and that sensitive technology

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92 Cited in Tolchin, 1992, p. 82.


transferred to Japan for the program, especially source codes for avionics systems\(^5\), would not be used outside the FS-X program. This latter provision derived from worries that Japan might use the U.S. military aircraft technology to develop a commercial aircraft industry that would eventually compete with U.S. firms.\(^6\) The Japanese, however, contended that these new provisions fundamentally altered the deal, and negotiations between American and Japanese officials broke off on 29 March 1989.\(^7\) No date was set for new talks.

By May 1989, the Bush administration put the FS-X back on track by signing additional agreements with Japan. Congress then had 30 days to act on the deal. The clarifying letters:\(^8\)

- ensured that U.S. companies would get about 40% of the workshare for the production phase of the program as well as for the $1.2 billion development phase;
- provided specific assurances that the technology

\(^5\) Software source codes are the basis of programs that enable pilots to control aircraft and weaponry electronically. Two groups of codes are those used in flight computers, which translate the pilot’s instructions to various parts of the plane, and those used in mission computers, which control the weapons, navigation system, radar, and electronic counter-measures. The United States was reluctant to provide the former. According to programmers, codes of either type are quite difficult to keep secret among engineers working together on a program. See Tolchin, 1992, pp. 87-88.


\(^7\) Nigel Holloway, "FSX Hits Turbulence," Far Eastern Economic Review, 13 April 1989, p. 32.

transferred to Japan was appropriately limited and carefully controlled; and

* offered a clear commitment that there would be significant technology flow back from Japan to the United States, specifying particular technologies of interest and conditions of U.S. access.

Under the terms of the new agreement, the technology transfer and flowback was to be monitored by a joint U.S.-Japanese technical steering committee, including representatives from the U.S. Departments of Commerce and Defense, and cochaired by general offices of the U.S. Air Force and the Japanese Air Self Defense Force.

U.S. technologies to be withheld from Japan included the four major systems to be developed by Japan: the fire control computer, the electronic warfare suite, the inertial navigation system, and the phased array radar. Also excluded were commercially sensitive technologies such as airfoil, carbon-carbon, and other high-temperature components, and very high-speed integrated circuitry (VHSIC), and militarily sensitive technologies such as the F-16 nuclear delivery capability, the advanced medium-range air-to-air missile (AMRAAM), and low-altitude navigation and targeting infrared system for night (LANTIRN).™ Most contentious, however, were the source codes for the aircraft’s digital flight control

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computer. Secretary of Defense Dick Cheney insisted that those codes be developed either solely by the U.S. manufacturer or solely by Japan. Japan rejected the former option, citing their inability to check and repair a black box. Instead, the JDA decided to develop the software using indigenous technology, which analysts at the time predicted might delay the program by as much as two years. The Japanese did receive, under the agreement, software codes to enable them to integrate their own fire control system into the aircraft; they had already been receiving similar codes under the F-15J coproduction.

The two Japanese technologies in which the United States was the most interested were the phased array radar and cocured, single-piece composite wing technologies. Some critics, however, contended that the deal was far from a two-way street, since these two technologies were not new and had been familiar to the United States for more than a decade. Indeed, a General Accounting Office report released in June 1989 concluded that Fuji Heavy Industries' carbon-fiber-and-resin composites technology had been rejected years earlier by

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100 In a typical F-16 sale, the U.S. would release only the "object code," enabling the customer to operate the aircraft normally. See Julian Moxon, "FSX Agreement Will Be Policed," Flight International, 20 May 1989, p. 28.

101 In response to this two-year delay, Japan's Air Self Defense Forces considered diverting part of its F-4EJ force to the FS-X's antishipping mission. See "Japan Considers Shift of F-4EJs To FS-X Mission," Aviation Week and Space Technology, 17 July 1989, p. 28.
several U.S. aerospace manufacturers in favor of thermal plastics.\textsuperscript{102} Dick Cheney countered that these critics fundamentally misunderstood what the United States was after; it was not necessarily the technologies themselves but the manufacturing applications developed by the Japanese that were of interest. Although the U.S. could use composites in aircraft wings, for example, they still have to be fastened to the aircraft. "A wing with no fasteners on the underside would be a significant manufacturing breakthrough," Cheney commented.\textsuperscript{103} Other observers commented that the Japanese certainly seemed to have confidence in their wing technologies, since they did not carry a back-up approach.\textsuperscript{104} The U.S. also hoped to take advantage of Japanese expertise in low-cost manufacturing and miniaturization of phased array radar components.

Cheney's views carried the day for the Bush administration. On 16 May 1989, a 52-47 Senate vote that cut

\textsuperscript{102} On the Japanese composite materials technology, see in particular the statements by George A. Sousa, Assistant Director, National Security and Internal Affairs Division, General Accounting Office, in \textit{Implications of the FS-X Aircraft Agreement Between the United States and Japan}, Hearings before the Subcommittee on Defense Industry and Technology, Committee on Armed Services, United States Senate, 101st Congress, 1st Session, 9 May 1989, pp. 175-179. See also Boatman, 13 May 1989, p. 845.

\textsuperscript{103} Morrocco, 8 May 1989, p. 18.

\textsuperscript{104} Statement of Dr. Vernon A. Lee, Vice President - Japan, General Dynamics Corporation, in Hearings before several subcommittees of the Committee on Science, Space and Technology, U.S. House of Representatives, 101st Congress, 1st Session, 11 May 1989, pp. 243-244.
across party and ideological lines approved the FS-X agreement with Japan.\textsuperscript{105} Overall, Mitsubishi Heavy Industries reportedly agreed to an approximately $480 million license fee, paid on 6 July 1989 to the United States for access to F-16 technology. Around 20 General Dynamics engineers had started to travel to Japan in mid-May, bringing with them the technical data on the F-16, primarily in the form of drawings and related documents, to initiate the formal joint development program.\textsuperscript{106}

Many participants in Japan were clearly quite disgruntled with the revised agreement. The Liberal Democratic Party seemed unwilling to air its dissatisfaction with U.S. anti-FSX sentiment in public, however, probably because it was distracted by the Recruit insider-trading scandal and the introduction of the three percent consumption tax.\textsuperscript{107} Rumors abounded among the Japanese firms involved, including Mitsubishi, that the program would be capped after the six prototype aircraft were produced.\textsuperscript{108}


\textsuperscript{107} Otsuki Shinji, "The FSX Problem Resolved?" Japan Quarterly, January-March 1990, pp. 72-73.

Defense and Industry in Japan: Why the FS-X?

At this point, it is appropriate briefly to step out of the case history of the FS-X aircraft and ask more directly exactly what Japan hoped to gain from the program. Who initiated the requirement for a new aircraft, and why?

As a rule, private industry plays a large role in defining the technical and tactical requirements for Japanese weapons systems. Michael Chinworth describes in detail, for example, the degree to which the Mitsubishi Electric Corporation participated in Japan's decision-making in the early stages of its procurement of the Patriot surface-to-air missile system. He writes, "The fact that the government would rely so heavily on an individual company in these respects...highlights the depth of resources and expertise in the Japanese private sector on defense matters."\(^{109}\) Of course, the same companies that assist in writing requirements and selecting system specifications may also act later in the process to design, develop, or produce those same systems; naturally, those companies will try to set policy that will serve their own broader interests in the longer term. In particular, they pursue defense-related research and development projects that they expect to have direct commercial applications, or to serve as catalysts for technological innovations with eventual commercial

\(^{109}\) See Chinworth, 89-04, pp. 10, 14-16, 19-20; quote from p. 40.
implications.

Arthur Alexander uses the example of phased array radar to demonstrate the degree to which "weapons requirements...are often determined more by the technical tastes of R&D engineers in the TRDI than by tactical and operational needs." Japanese engineers may know a great deal about the electronics involved in such systems, but there has never been a reason for them to learn how to integrate those electronics into a network of sensors and weapons, how to write the incredibly complex software that drives them, and how to use them once they are built. Their component technology -- the individual emitter-receiver elements -- is of innovative design and producible at low cost, but the Japanese have never figured out how to integrate them into a system that can actually work on an operational aircraft. Alexander quotes industry specialists: "They lack the threat data to make the system fully effective." Indeed, a Japanese company that produced and designed a surface-to-air missile confided to Alexander that detailed scenarios for the weapon's use were never provided by the Japanese military; the firm had to produce its own, based on publicly available information."

Many analysts have speculated that private industry must


play a role in setting the narrow requirements for weapons system development because the JDA lacks the skill to do so itself. Indeed, some go even further to suggest that, because of the JDA’s lack of combat experience and poor training regimen, military requirements actually have little to do with the shape and characteristics of Japanese weapons systems; the JDA does not know how to conduct legitimate, detailed threat assessments and translate those into a set of responsive weapon specifications in a meaningful way.

Combat training is simply not adequate to prepare Japanese troops for effective operation. For domestic political reasons, much on-duty time of Japanese soldiers is spent conducting Red Cross-style disaster relief operations.\(^\text{112}\) Crowded conditions force the Air Force’s F-15 exercises to be held hundreds of miles off the main island; pilots almost never gain experience in maneuvers at military speeds because the sudden acceleration would risk putting them in the path of commercial air traffic. They simply do not train under realistic combat conditions. One observer explains it this way:\(^\text{113}\)

The Japanese train under threat of extreme penalty for accident or failure. They therefore plan their training maneuvers carefully and to the most minute detail, first over and over again on the blackboard, then without a real target. Finally, they carry out one maneuver with

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\(^{113}\) Interviews.
a target whose location and behavior is pre-planned, pat themselves on the back, and go back to the base for tea.

Lack of ammunition means that pilot flying hours run at about 2/3 of U.S. Air Force levels; the supply of practice missiles is so tight that, on average, F-1 and F-4 pilots get one practice missile every two years. Because a pilot would benefit so little from this allocation, many squadrons assign all their practice missiles to one or two pilots, who each fire several under varying conditions. They then instruct their colleagues on the missiles' characteristics.¹¹⁴

The Importance of Civilian Aerospace

If coherent, detailed threat assessment did not drive the requirement for the FS-X, then there must have been another set of motivations. Clearly, there is a strong economic component to Japan's security policy. In terms of weapons procurement, this has translated into an inclination to structure defense spending so that it has a positive impact on the domestic economy. This strategy has been directly applied to the aerospace industry. Since 1954, MITI has put aerospace on a par with nuclear power and the information industry as a

key, targeted technological sector for the next century. In Japan, the commercial market for aviation has been a small part of this picture. Instead, the Japanese military has sustained the Japanese aerospace industry; it procures more than 75% of aircraft output. This dynamic may bode well for Japan's entry into commercial aircraft markets in the future, as "spin-on" of advanced civilian materials and electronics technologies becomes more important to the success of military programs. Defense sales can reduce costs in commercial product lines, letting the military budget bear some of the R&D costs for technologies eventually directed to non-military applications, and can expand the base of commercial production. In other words, "the military angle ultimately will help push Japan's technology lead in the civilian sector." The 1992 JDA white paper was explicit:


117 Michael W. Chinworth, "Japan's Dilemma: Rising Defense Budgets in an Era of Global Cuts," Breakthroughs, Vol. 1, No. 1, Fall 1990, p. 9. Chinworth has argued that this dynamic applies to sectors other than aircraft; he convincingly shows that Japan selected the Patriot surface-to-air missile system because of its potential benefits to domestic industry, including materials research, CAD/CAM capabilities, and radar applications to air
"High rigidity, lightweight alloy technology, originally developed as defense technology, has found its way into railway running stocks such as Tohoku and Joetsu Shinkansen 'bullet trains' as well as in fabricating automobiles and structural material for bridges."\(^{118}\) Of course, as pressure mounts for defense budgets to decline in the post-Cold War era, such spin-off successes provide excellent fodder for JDA's budget arguments.

Japan has long used military aircraft programs -- many of the co-production programs with the United States -- to bolster its own civilian industry. Several helicopter models used by the Self-Defense forces, co-produced with Western firms, have been translated into civilian models, and in some cases even exported in their non-military forms.\(^{119}\) The Mitsubishi 9-11 passenger business aircraft MU-300 (Diamond) uses much of the same tooling and machinery technologies as the F-15J; in the Komaki South plant at Nagoya, the production of F-15 and MU-300 parts takes place on the same equipment and production lines, although the final assembly lines are separate. Plant officials freely admit that they have learned much from that U.S.-licensed military aircraft co-production


program, including materials technology involving lightweight titanium, boron, and carbon.\textsuperscript{120} These civilian-military industry ties are cemented through institutional relationships. At any given time, MITI has up to a dozen seconded officials in key JDA positions, particularly in the aircraft ordnance/equipment bureau.\textsuperscript{121}

Defense industry officials in Tokyo admit that local development of weapons systems costs two or three times as much as building comparable systems under license, which in turn is roughly twice as expensive, on average, as direct imports.\textsuperscript{122} They hope, however, that co-production or indigenous development will pay off in the long run as Japanese firms learn valuable systems integration and other skills they currently do not possess. Indeed, they are hoping to learn not only modern design and production techniques from these collaborative military programs, but also elements of sales, marketing, and after-sales support, with a view to being able to provide these components of total aerospace programs in the future.\textsuperscript{123}


\textsuperscript{121} Chinworth, 1992, p. 17.


The selection of specific requirements for the FS-X program illustrates this point. Japan’s insistence, for example, on an active phased array attack radar for the aircraft seemed to many observers to be of limited tactical usefulness, adding unnecessary costs. If, however, MELCO’s private development of the gallium-arsenide semiconductor electronics used in the radar and its desire to commercialize the receiver-transmitter modules are taken into account, then the answer become clear: MELCO needed military demand for the system in order to ensure short-term profitability, and in order to take the technology to the level of successful commercial application.\textsuperscript{124} For example, MELCO has used the active phased array radars developed for the FS-X for a number of civilian applications, including collision avoidance radars.\textsuperscript{125}

TRDI’s Role

Japanese defense technology development is coordinated by the JDA’s Technical Research and Development Institute (TRDI). Because of an ongoing sense that defense spending was a burden on the Japanese economy, TRDI has historically managed its defense technology efforts according to their impact on the domestic civilian economic and technological base. In other words, it does not target technology development with an eye

\textsuperscript{124} Alexander, 1993, pp. 32-33.

\textsuperscript{125} Alexander, 1993, p. 23; and author’s interviews.
toward eventual application to specific weapons systems; instead, it focuses on technologies which seem most likely to benefit the commercial sector.

Thus, an important element of the Japanese strategy is much like one used in drafting professional football players. Rather than find the best player for a specific position, TRDI often "drafts" the best technology available regardless of the position it plays. What is important is that it is an "impact player" capable of producing benefits to the "team" over the long run. The U.S. security guarantee, of course, has contributed to a situation in which Japan has more flexibility in making these decisions. As long as the U.S. defense umbrella remained credible, Japan could afford gaps in its domestic defense technology as well as its deployed forces until it had sufficient time to develop indigenous capabilities.  

In terms of financing, TRDI tries to maximize the use of private sector resources for the development of defense technologies, most often issuing contracts to act as seed money for promising technologies already identified by and well advanced in the private sector. This situation minimizes government risk, but the system generally ensures payoff to industry through early promises that systems based on those technologies will eventually be developed. In other words, companies will fund their own R&D projects under the assumption that ultimately those costs will be reimbursed.

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through JDA production contracts. 128

This system works for Japan because of the degree to which distinctions are not made between military and civilian technologies. Michael Green quotes the JDA's head of research and development in 1990: "There is no black versus white, military versus civilian technology. All technology is just different shades of grey. It becomes military or civilian in application." 129 Because of the degree to which Japanese firms are not dependent on defense, this conceptualization applies not just to technologies or even products, but to facilities as well. Should military applications fail, fall prey to the budget axe, or simply not be needed, production space can be readily diverted to civilian product counterparts. 130 The fact that these potentially dual-use technologies are developed within the same physical and organizational space in Japan increases the probability that firms will take the risks inherent in new development. This is true not only of within-firm decisions, but is also a

128 Alexander, 1993, pp. 11-12; Chinworth, 1992, p. 35.


consequence of the tight keiretsu structure of the major Japanese defense companies; those firms will take risks with technologies that can be used by fellow industrial "family" members. Indeed, further coordination of application of technology resources is enhanced by common financing by the group bank, mutual directorships, cross-holding of equity, and frequent meetings of top-level decision makers.\footnote{Alexander, 1993, p. 28.}

**FS-X Post-Source Selection Development**

Japan's fiscal year 1990 TRDI budget heavily emphasized the FS-X program. Of a total budget of 103,240 million yen, or about $672 million, some 90\% was allocated to pure R&D activities, with 34.6 billion yen allocated to FS-X development. The money was allocated to detailed overall design as well as manufacture of a forward-fuselage specimen for ejection testing.\footnote{"FS-X Program Takes Large Slice of Japanese Research Budget," *Flight International*, 28 March - 3 April 1990, p. 17.} The expected IOC date for the aircraft had, as of mid-1990, slipped to 1999, and total development costs increased from 176 billion yen ($1.06 billion) to more than 200 billion; unit cost figures rose to almost 7 billion, against an original production estimated of 5.15 billion per copy.\footnote{"JDA Seeks Fighter Power," *Flight International*, 4-10 July 1990, p. 17.}
Only a few months later, a JDA review indicated that the program would cost even more, with a total development cost of 260 billion yen ($1.44 billion). Officials in Tokyo were uncertain how the Japanese Diet would respond to the request for additional funds that would be made as a part of the JDA's preparation for a new five-year defense program covering all military expenditures. The Japanese at this point began to point the finger at General Dynamics, publicly urging the American firm to lower its FS-X costs. General Dynamics countered with a proposal to scale back the entire project to cut expenses, but the Japanese rejected that idea; General Dynamics also offered to appear before the Diet to explain why costs jumped as the project grew more technologically complex.

Fundamentally, however, the cost increases had to do with Mitsubishi Heavy Industries having to develop the software source codes for the flight control system by itself. Apparently Japan continued to hope for substantial assistance from General Dynamics on this part of the program. "Originally, the idea was that we could receive new F-16 technology," commented Nishihiro. "That is not coming in. So the original objective of pooling technology from both sides has been lost." A number of other characteristics of the development program changed into 1990, including raising the

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number of prototypes to be produced and increasing the number of changes from the original F-16 design. Mitsubishi and General Dynamics continued to place the blame on one another for delays, huge cost overruns, and technical problems. According to one American businessman involved in the project, the Japanese government and industry "always say it’s General Dynamics’ fault. When I talk to General Dynamics, they say the whole program was not as carefully scoped out as it should have been, that there are a lot of changes Mitsubishi heavy wants to make that cost money."¹³⁶ For example, Seiki Nishihiro, recently retired as Japan’s Vice Minister of Defense and still a JDA adviser, blamed the American contractor for the cost increases, claiming it had "doubled its original quote." Japanese defense and air force officials pointed, for example, to U.S. insistence on setting up a second FS-X production line at General Dynamic’s Fort Worth Division, despite the small number of aircraft involved. But Dr. Vernon A. Lee, then General Dynamics’ vice president for Japan, countered that he had "supplied information to the Japanese defense agency in good faith" in response to its questionnaire several years ago, and that the American side had not been at all involved in converting that information into a budget. "And there have been many changes in the

program since then that we don't have any control over."\textsuperscript{137} Lee is correct in that the original General Dynamics proposal involved development in the United States and stretching over only a 3-1/2 year period, the construction of only two prototype aircraft, and few changes in the airframe since all systems and subsystems were to be identical to the F-16 except for the Japanese-developed radar, inertial reference system, integrated electronic warfare system, and mission computer; the nature of the codevelopment program changed all of these factors.\textsuperscript{138} The two sides have also bickered over differing interpretations of the vaguely worded FS-X agreement between the Japanese and American governments.

One primary cause of the tension between the Japanese and American contractors during the course of the FS-X development is the differing emphases the two countries place on various procurement goals. The American tradition of weapons design and procurement stresses achievement of performance specifications, regardless of cost and schedule penalties that might have to be paid to achieve performance target. Japan's philosophy differs in its emphasis on budgeted costs as the dominant program target.\textsuperscript{139} Because the JDA is not a powerful


\textsuperscript{138} GAO, June 1992, p. 19.

bureaucratic player in Japanese domestic politics, it is extremely reluctant to return to the Ministry of Finance and the Diet for additional funds once a project is approved and budgeted; most Japanese weapons programs therefore design and produce to budget, and stop there. The initial cost barrier remains inviolable. In the FS-X case, when cost overruns became apparent, the JDA had two choices: accept the higher costs, or cancel the program. Because of the FS-X's central role in Japan's strategic scheme for the aerospace sector, and also due to its position in the international political spotlight, the latter was not a realistic option; Japan was forced to adopt the American procurement pattern in this case. The absorption of the higher FS-X costs has meant a reallocation of R&D resources throughout Japan's defense budget, slashing funding or stretching out the timing of competing programs.\textsuperscript{140}

As of late November 1990, the cost of the development program had nearly doubled; both Japanese and American critics worried that the FS-X would be so late and expensive that it would be nearly obsolete by the time it got off the ground. Japanese officials privately said that the only thing saving the fighter from cancellation was fear of loss of face among

\textsuperscript{140} Alexander, 1991, p. 27. The degree to which at least some competitors for those resources acknowledge the FS-X's strategic importance for Japan and almost gladly accede to its increasing share of R&D funds is astonishing. Author's interviews, Tokyo, Japan, October 1991.
both governments. Nishihiro explained: "There is a kind of inertia in the Japanese executive branch, a feeling that if they decided to scrap the program, it would indicate their post-judgment was wrong." Nishihiro's comments were typical: "The FS-X project itself has completely lost its effectiveness. If things are left on the course they are now, there is the possibility that the project will evaporate into thin air." Doubts that the Japanese Diet would allocate more money for the aircraft, particularly given the decline of the Soviet threat and the Diet's anger over the JDA's advocacy of a strong Japanese military presence in the Persian Gulf, were rampant.

In fact, Mitsubishi freely admitted that developing an Japanese version of the aircraft's flight control software would add only about 20 billion yen to the overall development price tag. The main reasons for the cost overruns instead had to do with the cost of Japanese capital. From 1985 to 1989, when the FS-X was on the drawing board, Japanese manufacturers needing capital took advantage of their inflated share prices at home to issue warrant bonds on the European market, and then swapped the dollars back into yen at favorable prices. As a result, there was almost no net cost for R&D funds for Japanese firms. After Japan's stock market collapse, however,


those companies now have to pay higher real costs for their capital.¹⁴³

Even more important in explaining the FS-X’s cost overruns, according to some observers, was the lack of an appropriate technology base at Mitsubishi and other Japanese firms. In particular, the much-heralded Japanese process for making the aircraft’s entire wing from carbon-fiber composites turned out not to be as well-developed as once thought. As designers began to take the FS-X’s real operational requirements into consideration, they began to worry about how to maintain the wing’s quality during manufacture and when in service, and how to repair it if it were damaged in combat. Rumors started to surface that the wing design would be replaced with ones fabricated from more conventional materials.¹⁴⁴

In mid-1991, the TRDI launched a new three-year, $7.2 million basic research program, conducted primarily by Mitsubishi Heavy Industries and Fuji Heavy Industry, focused on aerodynamic study of a new Japanese fighter with superior maneuverability and stealth characteristics than the American F-22.¹⁴⁵ This first stage of the program was to concentrate on the development of a program for digital wind tunnel tests,


wind tunnel models, and research into new materials, with research into mission avionics and other systems to follow later.

This new research effort was approved in conjunction with revelations of a further two-year schedule slippage and continued cost overruns for the FS-X, at this point scheduled to continue development through 1998 at an additional cost of 115 billion yen. Original unit production cost estimates of 4.7 billion yen ($35 million) had escalated by almost 100% to 8.4 billion yen, making the FS-X the world’s costliest fighter in its class.\footnote{146} As of mid-1991, the plane’s first flight was slated for 1995, with an IOC of 1999, but no firm fixed production schedule after development was completed. At that time, about 20% of the 300 engineers working on the aircraft at Mitsubishi’s Nagoya location were American, with further participation from Japanese subcontractors Kawasaki Heavy Industries, Fuji Heavy Industries, Shin Meiwa, and Japan Aircraft Manufacturing Company.\footnote{147} Preliminary design work was well under way, with detailed design scheduled to begin in mid-1992.

Modifications as of mid-1991 to the basic F-16C Block 40 design included a 16-inch aft fuselage plug and a 25 percent larger, co-cured composite wing. The aircraft’s canopy was to


\footnote{147} "Joint FS-X Team at Work; Detailed Design Phase To Start Next Year," \textit{Aviation Week and Space Technology}, 29 July 1991, p. 44.
be reinforced with a bow frame to provide increased birdstrike protection, and its nose radome shape lengthened to fit a Mitsubishi Electric Co.-made phased array radar antenna. Japan was to design and build the aircraft's empennage, which was to be similar to the F-16's, but with a slightly larger horizontal stabilizer. A single General Electric F110-GE-129 engine, with a 29,000-lb thrust, was to power the aircraft. Ishikawajima-Harima Heavy Industries was to assemble the powerplants in Japan and build several of their components. [insert figure from 1992 GAO report, p. 11, differences between Block 40 F-16 and FSX]

Program difficulties led some elements of the JDA in late 1991 to consider cancelling production plans for the FS-X, developing it only for research purposes instead. A feasibility study on restructuring the program along those lines was launched in autumn 1991.\textsuperscript{148} If the FS-X were scrapped, Japanese officials said, the immediate alternative would be an F-15 multi-role fighter. Japanese technologies for the FS-X, particularly the composite wing and phased array radar, would then be applied to the new Japanese aircraft

program.149

In the meantime, FS-X development work continued, with
the Air Self Defense Force beginning flight tests in November
1991 of an engineering model of the MELCO phased array radar,
flown in a modified Kawasaki C-1 testbed aircraft. Testing of
the $76.8 million radar was scheduled to continued throughout
1992. The TRDI received $610.5 million for FS-X development
in the 1992 defense budget,150 and Mitsubishi began
construction of the first wooden mock-up of the aircraft in
May of 1992.151 That model was finished and unveiled two
months later, revealing that in the transition off the drawing
board the aircraft lost its vertical canard-wings under the
fuselage air intake. The TRDI claimed that the required
maneuverability would be obtained by decoupled yaw and
maneuver enhancement controls. The removal of the canard
wings saved about 100 kg of structural weight, but the TRDI
strongly denied that weight problems prompted the design
change.152 At this point, the FS-X empty weight was estimated
at 9600 kg, and maximum take-off weight at 22,000 kg.

149 John Boatman, "Japan Casts Doubt on Future of FS-X," Jane's

150 "Japan Cuts Defense Spending Plans Sharply As Regional
Tensions Ease," Aviation Week and Space Technology, 20 January

151 Naoaki Usui, "Mitsubishi To Construct Wood Model of FSX

152 Kensuke Ebata, "Japan Shows FS-X Fighter Mock-Up," Jane's
An extensive review of the mock-up led to more than 300 minor design improvements suggested by TRDI. After the late 1992 review, Japanese officials began to sound much more optimistic about the program, predicting a start of construction on the first prototype in the second quarter of 1993 and first flight in the third quarter of 1995. The Air Self Defense Agency developed a production schedule in November of 1992 calling for 12 aircraft to be produced annually between 1996 and 2001, for a total of 72, to replace the F-1s, and additional aircraft procured as needed to accomplish other missions.\textsuperscript{153} According to Yukata Hineno, managing director and general manager of Mitsubishi Heavy Industries' aerospace and special-vehicle headquarters, there were "no additional delays" after the initial disagreements about General Dynamics' workshare and Japanese access to software source codes. On the source codes, Hineno added, "The source codes for the F-16 are not going to be released. That was the final determination. But we believe that our knowledge with the CCV is sufficient for us to develop the source codes. The flight-control system will be made in Japan."\textsuperscript{154}


Throughout the development effort Japan had come under fire for not living up to its commitments to share its FS-X technology. U.S. System Program Office officials commented that Japan has never routinely initiated actions to facilities access to its technologies; instead, the United States always has to request information, frequently encountering delays.\textsuperscript{155} In response to these criticisms, MELCO held a June 1992 briefing at the U.S. Department of Commerce in Washington on the performance of its phased array radar. U.S. officials present at the closed session said that several features of the radar system, particularly its use of superfast integrated circuits based on gallium arsenide and monolithic microwave technologies, could have broad commercial applications. For example, the integrated circuits that power the FS-X radar could also be used to make pocket telephones, or to operate electronic road maps in automobile dashboards.\textsuperscript{156} Many U.S. representatives, particularly from Hughes Aircraft Co. in El Segundo, CA, and Westinghouse Electronic Systems Group in Baltimore, followed up with private interviews with MELCO engineers.\textsuperscript{157} Mitsubishi confirmed that Hughes and Westinghouse were seeking technology for making electronic modules that transmit and receive radar signals for both

\textsuperscript{155} GAO, June 1992, p. 20.


military and civilian applications; the FS-X multipurpose radar contains as many as 1,300 transmit-receive modules that electronically steer radar beams.\textsuperscript{158} Apparently the two American firms wanted access to the Japanese information in order to compete with Texas Instruments in active phased array radar technology. As early as 1991, Japanese officials had offered MELCO's phased array radar technology in return for access to U.S. computer software expertise; it is clear that Japan wanted assistance with the source codes for the FS-X flight management and fire control systems.\textsuperscript{159} Through 1992, the United States refused to provide Japan with the sensitive software technology. In July 1993, MELCO signed an agreement to supply the U.S. Air Force with technical data on the phased array radar, along with five sample modules. The Air Force agreed to pay Mitsubishi an undisclosed amount for the modules.\textsuperscript{160}

The JDA 1993 budget request sought a record-high allocation for the FS-X, which had completed its basic engineering phase in June 1992. The 1993 Defense Agency request was for 107 billion yen (\$823.08 million) for the aircraft to build five prototype airframes (three for flight


testing and two for ground testing), up substantially from 1992's allocation of 76 billion yen ($602 million).\textsuperscript{161} By the end of 1992, the project had consumed 211 billion yen ($1.67 billion), far above the original development budget of 165 billion yen ($1.31 billion).\textsuperscript{162} That 1993 request boosted overall FS-X development costs to nearly 300 billion yen ($2.5 billion), by far the costliest aircraft ever developed by the Japanese Air Self Defense Force (in fact, the costliest military project of any kind ever developed in Japan).\textsuperscript{163} These figures, coming within the context of the overall Japanese defense slowdown -- an increase of just 3.6 percent over 1992, the smallest growth since 1960 -- reveal the priority the TRDI accorded to the FS-X program. The Japanese government eventually approved only 96.5 billion yen ($762 million) for the aircraft in 1993, about 10\% less than was initially requested.\textsuperscript{164}

In October 1992, General Dynamics announced that it had successfully co-cured and assembled composite components for the FS-X. Employing the co-curing process developed in Japan, the American firm fabricated two integral wing fuel tanks


\textsuperscript{162} Naoaki Usui, "Japan Boosts Fighter Funds," \textit{Defense News}, 24-30 August 1992, p. 3.

\textsuperscript{163} "Industry Outlook," \textit{Aviation Week and Space Technology}, 1 March 1993, p. 11.

about 3 ft. by 13 ft. in size and representing about one quarter of an FS-X wing. The first item was constructed to verify the parameters and performance of the tooling used in the co-curing process, and the second was to be used in fuel tank pressure tests. This event represented the first tangible transfer of Japanese technology under the FS-X agreement.

Technology transfer issues heated up again in early 1993, when U.S. defense officials balked at reports that the JDA was restricting access to about 50 subsystems for the aircraft developed by Japanese companies. The JDA claims that these items use technologies developed solely by Japan and therefore qualify as "non-derived," meaning that their Japanese developers have sole exploitation rights. A 23 February 1993 report in the Japanese financial daily Nihon Keizai Shimbun said that FS-X subcontractors were claiming patents on items such as Yokogawa Electric’s multi-function liquid-crystal display technology, a holographic display from Shimadzu, an onboard cooling system for avionics, and radar

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165 The tooling, constructed from Invar, an alloy with thermal expansion properties matching those of the composite materials employed in the aircraft, is a critical part of the co-curing process.


absorbing materials.\textsuperscript{168} One U.S. source explained, "The U.S. position is that everything is derived, until proved otherwise. My understanding is that the Japanese side it providing a rationale to try to convince the U.S. government that the technology is non-derived."\textsuperscript{169} Most American observers claimed that Japan's actions had to do with political problems stemming from its economic recession. In order to justify the FS-X program, Japanese officials, within the context of the workshare agreement, were trying to demonstrate that the aircraft provided jobs to Japanese workers and supported the Japanese industrial base.

The JDA's 1994 budget request included 97 billion yen ($932.7 million) to continue prototype development work on the FS-X.\textsuperscript{170} As of late 1993, Mitsubishi Heavy Industries had completed a left main wing to be used for FS-X static testing. The spars, major ribs, and underwing surface skin were made in a single co-cured piece of carbon-fiber reinforced plastic; an upper surface made of the same material was to be held on with fasteners.\textsuperscript{171}


\textsuperscript{169} Quoted in Bailey, 17-23 March 1993, p. 17.


\textsuperscript{171} "FS-X Wing Tests To Begin," \textit{Aviation Week and Space Technology}, 1 November 1993, p. 17.
Japanese Security after the Cold War

The defense cooperation agreement between Japan and the United States states that Japan has responsibility for protecting its territory, airspace, coastal waters, and sea lanes out to 1,000 miles. Into the early 1980s, Japan's strategic environment was affected by U.S. urgings that Japan more fully share the burden for its own defense, and a growing sense that the United States was no longer as reliable an ally as it had been in the past. These perceptions were strengthened by the U.S. defeat in Vietnam, ongoing discussions in the late 1970s of a possible withdrawal of U.S. troops from South Korea, the Soviet invasion of Afghanistan, and the increased buildup of Soviet forces in the Far East.\(^{172}\) The latter held particular significance for Japanese commentators, who stressed the deployment of Soviet Delta-class SSBNs in the northwest Pacific and the Sea of Okhotsk in the late 1970s and the resultant strengthening of Soviet conventional forces in the region to provide direct protection for them.\(^{173}\)

In the mid-1980s, some Japanese observers began to question the size and effectiveness of the Soviet forces

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deployed in the Far East. In particular, the September 1983 Korean Air Lines incident, in which Soviet interceptors failed to find a Korean Boeing 747 and allowed it to fly through Soviet airspace unimpeded for more than two hours before shooting it down, indicated a lack of effective early warning capability, inadequate command and communications, and poor interaction between Soviet headquarters and front-line units.174

Even after the relaxation of tensions in the East-West relationship in the late 1980s, Soviet commentators were reluctant to conclude that the Cold War was over in the Asia/Pacific region.175 The JDA's 1992 white paper was the first acknowledgement that a revision of its 1976 National Defense Program might be appropriate. It noted that tensions had eased considerably because of the collapse of the former Soviet Union, but cautioned that China and North Korea posed new challenges.176 In terms of the threat from the air, Japan feared, beginning in the late 1980s, the introduction of

174 "Japan Plans New Fighter As Soviet Threat Changes," Aviation Week and Space Technology, 12 March 1984, p. 82.

175 Chinworth, Breakthroughs, 1990.

Soviet MiG-29, MiG-31, Su-25, and Su-27 fighters, and Tu-26 and Su-24 bombers, into the region; Soviet arms transfers to its major allies, particularly MiG-23s and MiG-29s to North Korea, were also worrisome.\textsuperscript{177} Some analysts have, argued that, as is the case in the rest of the world, Japan's threat assessment task has become even more challenging in the wake of the Cold War, since the new environment brings with it diminished certainty and predictability.\textsuperscript{178}

It is clear that Japan has depended heavily on U.S. aircraft to accomplish basic defense missions.\textsuperscript{179} The Japanese Air Self Defense Forces (ASDF) are equipped with the F-4J and F-15J, both designed by McDonnell Douglas and coproduced with Japan, and the domestically designed and developed F-1. These aircraft must, in the event of hostilities, defend the Japanese fleet, which for political reasons cannot possess aircraft carriers, and protect the mainland and its approaches. Traditionally, the ASDF has operated under the assumption that the United States will have established air superiority over Japan and its approaches in the event of war.\textsuperscript{180}


\textsuperscript{178} Chinworth, 1992, pp. 6-7.

\textsuperscript{179} Samuels and Whipple, p. 14.

Given this threat environment, and since Japan has relied so heavily on the U.S. security umbrella throughout the post-war period, it is natural that Japan might wish to become more self-reliant militarily as it views the decline of American economic and industrial capability.\textsuperscript{181} A United States in decline may become less willing to guarantee the security of its chief economic competitor. This view of the United States is shared by the Japanese public, which, according to a March 1991 opinion poll, considered the U.S. less trustworthy after the Persian Gulf war than before.\textsuperscript{182} This push toward self-reliance is likely to be intensified by the consequences of U.S. budget and personnel cuts in the region, such as a recent review of U.S. Pacific Command field training exercises which may result in a scaling back of joint exercises with Japan.\textsuperscript{183} Such considerations may have been reflected in a 1987 decision to define TRDI’s role to include research that is not immediately identifiable as potentially applicable to the civilian sector; perhaps the JDA anticipates the need to


develop technologies with solely military applications.\textsuperscript{184}

If this is the case, then the strategy which dominated the FS-X selection -- harnessing a military aircraft development program primarily in order to further commercial industrial goals -- may fall by the wayside, as Japan realizes that it will be obligated to provide for its own defense in the future.

Predictions Revisited: Conclusions About the Japan and FS-X

While many similarities can be gleaned from the U.S. and Soviet/Russian cases, Japan clearly presents a very different pattern of behavior. First of all, Japan's military establishment has not exhibited the capability to undertake extensive threat analyses (I-A, I-B). Since the end of World War II, Japan has relied on the United States for assessments of the technical, tactical, and operational challenges presented by potential opponents' current and projected developments in weapons technologies and systems. Indeed, it seems to have been the case that realistic threat assessment had very little to do with the setting of the FS-X requirement (II-C), with the JDA repeatedly insisting on sets of tactical parameters (such as the active phased array radar) that bewildered its American counterparts. Some of what were initially hard and fast requirements for the aircraft, such as

the need for two engines, seemed mysteriously to disappear when other concerns emerged.

Those other concerns had to do with the building of an indigenous aircraft-related technological and industrial base. In a twist on the predictions offered by international systems theory, technology was indeed pursued for technology's sake (I-C), but in a deliberate, strategically planned manner. The important organizational and bureaucratic constituencies in Japan's aircraft design and production sector acted in concert to protect what they had agreed was their long-term core mission (III-B): to support the development of Japan's own aircraft research, design, and production capability. Individual players within this "united front" exhibited classic organizational behaviors in their efforts to maximize their singular roles in fulfilling this mission, including, for example, Mitsubishi Heavy Industries' continued early efforts to convince the Japanese government that it was possible to develop and produce the FS-X domestically at a competitive price. When foreign policy concerns finally forced Japan to submit to the codevelopment option, the JDA and Japanese contractors continued to pursue a dual adaptation strategy of cooperation and competition with their American partners (III-D); Japan would work with the United States to design and produce the aircraft, but would staunchly continue to lobby for and protect domestic technological interests at every opportunity.
Chapter Nine:
Institutions, Norms, and Convergence
In the Post-Cold War World

Given the evidence presented in the case studies, we can conclude that national norms, related to each country's unique definition and conceptualization of its own national security, influence the development and interactions of domestic institutions. We have seen that this domestic institutional structure is a prism, through which perceptions of the international environment (the threat) and internal factors (domestic and bureaucratic politics) are filtered. Finally, we have seen that norms derive from each country's own perceptions of its security needs, which stem largely from their international environments and perceived responsibilities: the United States' and Soviet Union's status as contending superpowers, and therefore their sense of urgency about responding to narrowly military-technical imperatives, as opposed to Japan's longer-term and more comprehensive technonationalist approach, which has long held that economic and military security cannot be separated. The ongoing evolution of norms is intimately tied to the flexibility and adaptability of national institutions.

This concluding chapter will revisit the major analytic points to emerge from the case study material regarding the relevance of the menu of six norms to the institutional structures and procurement outcomes of the United States, Russia, and Japan. In the process of doing so, it will
highlight some of the more important evidence to support the conclusions being drawn about the explanatory value of and interplay between norms and institutions. Finally, it will draw conclusions about the changing nature of each country's norms as the shape of the post-Cold War world becomes clearer.

Cold-War Normative and Institutional Patterns

Military-Technical Norms: Performance

It is clear in the U.S. and Soviet cases that norms related to weapon system performance exhibited tremendous influence when both countries reacted to threats from the international environment; indeed, the evidence presented here suggests a two-stage pattern. Early exploration and consideration of the need for new aircraft took place in both countries because of the perception of broad changes in the threat environment, and the concomitant need for new performance capabilities. This broad early activity coalesced into a specific requirement for a specific aircraft, however, due to some catalyzing event in the international environment. Once requirements were set, the institutional structures of the two superpowers dramatically affected their abilities to carry out performance goals; in the United States, competitive bureaucratic and organizational pressures led to "piling on" of technical and performance parameters, while in the Soviet Union inefficient and sometimes perverse institutional incentives mitigated against the possibility of initial
aircraft specifications being fulfilled. Japan's orientation
toward performance norms stands in stark contrast to the two
superpowers. Performance goals in Japan were clearly
subordinate to other goals of autonomy, diffusion, and
nurturance.

**US/USSR: Broad Changes in the Threat Environment.** In the
United States, for example, the F-15 and F-16 were conceived
largely in reaction to the lessons learned from the Vietnam
war. Before Vietnam, the U.S. Air Force had shifted away from
the World War II and Korean War-era principles of dogfighting
air-to-air combat, and had begun to rely on advanced in radar
and electronic -- in particular, on beyond-visual-range
missiles. This philosophy meant that high top speed would be
the most critical performance parameter in future air combat.

The experience of Vietnam, where American aircraft flew
against highly maneuverable Soviet MiGs, revealed the defects
in this new philosophy. Problems with distinguishing friend
from foe quickly made visual acquisition one of the primary
rules of engagement, and this meant that U.S. pilots who had
been trained for interceptor missions, and U.S. aircraft which
had been similarly designed, had to gear up instead for
dogfights. As a result, early in 1965, high-level Air Force
officials began to argue for equipping existing tactical air
superiority fighters with guns, in anticipation of fights at
close range where positive visual identification of the enemy
would be required. They also began studying the possibility
of building a new, highly maneuverable air-to-air fighter, an idea which would eventually evolve into the F-15 and F-16.

The F-117 was similarly borne of American observations of combat experience, in this case the October 1973 war between Israel and Egypt. The Soviet Union had been developing new surface-to-air missiles in ever-growing numbers, and were mounting more recent models on tracked vehicles so that they would be harder to map than they had been in Vietnam. The October War highlighted the need for a drastic new technical or tactical development in the ongoing struggle between air offence and air defense. Egypt's use of the new Soviet SA-6 missile, with its new and improved tracking radar, rendered Israel's jamming equipment ineffective. Israel incurred heavy losses in the air and on the ground because its assumed air superiority was not achieved. The U.S. Air Force carefully noted these lessons: there is always a risk of surprise in the war between electronic offense and defense, and surprise can be very costly. Stealth technologies promised to offer the advantage of being relatively little affected by changes in frequency and waveform, and therefore immunity to those surprises inherent in electronic warfare techniques.

A similar pattern of broad new threats characterized early thinking about the F-22. In particular, American aircraft passing over a Soviet airfield near Moscow in 1978 discovered two new series of new fighters. U.S. Air Force planners were concerned not only with the sheer numbers of
these new aircraft, but also with their quality. Soviet advanced in airborne radar technology (leading to a lockdown/shootdown first control capability), air-to-air missile technology, maneuverability, and acceleration rendered their new planes equal in many respects to the F-15 and F-16, according to many analysts. Western air forces in the late 1970s were similarly concerned with the growing Soviet arsenal of surface-to-air missiles. At that time, the Warsaw Pact had developed a SAM network sufficient to constitute a barrier. Although it was not impenetrable, it was assumed that it would cause major attrition of NATO aircraft in the opening hours of hostilities.

A stealthy F-22 would be able to thwart this Soviet SAM barrier, and would also prove effective against their new generation of fighters. U.S. intelligence had revealed that the Soviet fighters carried large, powerful radars and long-range, radar-guided missiles; clearly, low observability was not one of their priorities. Soviet pilots instead apparently were to use radar, missile, and maneuverability improvement to achieve a first-look, first-shoot advantage over an opponent. The stealth capability incorporated into the F-22 would turn the Soviet tactic into a handicap, decreasing the range over which their fighters could detect and track a target.

Soviet specifications for the Su-27 and MiG-29, like those for the F-15, F-16, and F-117, were set in response to the lessons learned from the experience of air combat in the
Vietnam and Middle East wars. In addition to the difficulties with identify-friend-or-foe inherent in the reliance on beyond-visual-range missiles, the Soviets also observed that North Vietnamese fighter crews, trying to break through the American fighter screens set up around penetrating bombers, employed intermittent rather than massed strikes. These carefully planned surprise attacks, based on rapid maneuver capability, were essential to the success of the North Vietnamese strategy. The Soviet Air Force diligently learned the lesson that within-visual-range dogfighting, requiring high maneuverability, was the wave of the future in fighter aircraft, and conceived the MiG-29 and Su-27 accordingly.

**US/USSR: Specific catalyst.** As stressed earlier, in the Cold War-era United States and Soviet Union, a broad sense of a changed threat environment was not sufficient to send a well-defined new aircraft through the procurement pipeline. A specific catalytic event determined the timing of vague notions of a need coalescing into a specific requirement for a new aircraft. In the U.S. case, this event forced a resolution of the domestic political debate over the need for a new system and its characteristics. It enabled the bureaucratic and organizational players to argue that the threat was an urgent one, and therefore established the system firmly in the weapons procurement pipeline. By contrast, the Soviet Union took its cue from specific information about the Western system which the Soviet aircraft would be forced to
counter in combat; Soviet designers were unwilling to move forward until they knew precisely what they were up against.

For the F-15, early stagnation, delay, and confusion about what the new aircraft should look like was abruptly changed when, in July of 1967, the Soviet Union exhibited six new aircraft designs and upgrades to several older planes at the Domodedovo air show. In August of 1967, the U.S. Air Force issued a final, definitive request for proposals to private contractors, this time focusing on the need for air superiority, without which the other aerial missions which has been under consideration — close air support, interdiction, and high-speed intercept — would either be too costly or impossible to conduct. The F-16 similarly languished until the 1973 October War jolted tactical planners into the realization that numbers of aircraft could be as critical as top performance in air superiority battles.

The October War was also a critical catalyst for the development of the F-117. Stealth technology had been around for over a decade, primarily having grown out of work done by Dr. Leo Windecker. It was not until after the Middle East war, however, that DARPA in 1974 started the Harvey program, inviting five companies to participate in a competition to design a low-observable fighter aircraft.

Soviet planners and designers responded to a different kind of catalyst. When they had identified a need for a new type of aircraft, rather than jumping immediately into designs
of their own, they waited to gauge Western interpretations of the new tactical requirements. They then designed their next generation of aircraft in response to the Western, primarily American, analogs. According to interviews with Soviet designers, the point was not to copy American technology, but instead to wait until there was concrete, well-defined evidence of the threat which had to be answered, and then to construct a system meticulously around that specific threat in order to defeat it. The Su-27, therefore, was a deliberate and careful response to the F-15, and the MiG-29 to the F-16. Indeed, Sukhoy designers have revealed that they had to return to the drawing board at one point during the development of the Su-27 solely because simulated tests revealed in mid-process that their evolving design was not capable of defeating the F-15 in combat.

**US/USSR: Institutional capacity to implement performance norms.** Performance norms were therefore of high priority for both the United States and the Soviet Union. The institutional structure of the two superpowers, however, affected their capacities to respond to these threats in radically different ways. In other words, each country's responses to their perceived strategic and tactical challenges was filtered through its domestic institutional environment. In the United States, the need to build domestic coalitions around an aircraft in order for it to make its way through the procurement pipeline, and the competitive nature of the
procurement process (including both competition between contractors and competition between armed services), tended to encourage the addition of unnecessary and sometimes irrational performance capabilities to fighter aircraft. American weapons frequently have more bells and whistles than they really need. The monopolistic Soviet procurement process, on the other hand, dramatically narrowed the technological and performance options in the aircraft available to the Soviet Air Force. Soviet weapons designers responded to incentives which encouraged them to stress rapidity and quantity of aircraft delivery over quality and technological sophistication. The Soviet Air Force had no levers to persuade the defense industry to produce the kinds of aircraft it wanted.

In the case of the F-15, institutional competitiveness revolved around the Air Force's obsession with developing single-service, single-mission aircraft. At many points in the early and middle stages of the F-15's development, Secretary of Defense Robert McNamara tried to implement principles of commonality, in which the Air Force and the Navy would share aircraft designed to perform multiple missions in order to save money. The most critical threat to Air Force autonomy came in 1966, when the Pentagon began to consider the possibility of commonality between the FX (the F-15 precursor) and the Navy's VFAX attack aircraft. The 1968 decision to optimize the F-15 exclusively for the air superiority mission
was made, at least in part, to differentiate it from the Navy requirement and ensure the design and development of a separate aircraft. Similarly, the later decision to include only one crew member was intended as much to distinguish the F-15 from its Navy counterpart as it was to save the 5,000 pounds in additional structure and systems.

The F-15 continued to weather threats to its single-service autonomy well into its development. In mid-1971, the Secretary of Defense ordered the Navy to investigate the possibility of a naval version of the aircraft. Here we see the first of many examples of the armed services using their control over information and expertise in order to circumvent outside pressures. Although McDonnell Douglas responded to the Pentagon's request with a minimum modification which increased the aircraft's weight by only about 2,300 pounds for carrier suitability, the Navy created a Fighter Study Group to do its own analysis. The latter study concluded that a much more dramatic weight increase and the addition of a Phoenix missile would be necessary, and enabled the Navy to argue that the increase in weight and drag would affect performance and cost to the point that aircraft would be unacceptable for its purposes. In addition, the top officials of the Air Force and the Navy agreed to present a unified view to Congress that their aircraft were designed for completely different missions; the common front, helped each protect his own service's programs. Civilian officials bowed to the expertise
of the uniformed officers in complex technical and tactical matters, which permitted the service chiefs to use their control over expertise to gain control over resource allocation.

Early F-15 development was also influenced by within-service debates over the mission or combination of missions the aircraft should be assigned. As of April of 1966, in order to satisfy a variety of Air Force constituencies, the F-15 was defined as a Mach 3 ground attack and intercept aircraft, intended to function as a superior air-to-ground fighter as well as a counter for the expected Soviet bomber threat of the mid and late 1970s. We have already seen that the air-to-ground mission was abandoned largely in order to differentiate the F-15 from its naval counterpart, but even after that decision was made, many in the Air Force remained preoccupied with the issue of top speed. The latter characteristic, generally thought of as more important for interceptors than for dogfighting air-to-air combat fighters, grew in importance as the threat posed by the Soviet MiG-25 Foxbat interceptor became an object of discussion in Congress. Here, once again, we see weapons performance, the response to the Soviet threat, being filtered through the institutional environment of the U.S. weapons procurement process. Many in the Congress, which was of course responsible for continued funding of the aircraft, complained vigorously throughout 1968 that the Air Force was planning for an American aircraft to
come on line in future years that could barely compete with what they thought the Soviets had in hand at the time; it was difficult to explain to the Congress that the MiG-25 and F-15 were designed for completely different missions and hence should not be matched characteristic for characteristic. It was extremely unlikely that the MiG-25, intended solely for high-altitude intercept missions against American bombers and reconnaissance planes, would ever even encounter the F-15, let alone engage it in aerial combat. Nevertheless, the need to satisfy Congressional concern about the Soviet aircraft certainly helped to ensure the single-service quality of the F-15, but it also resulted in increased top speed and many other higher technical and performance parameters than were necessary.

Because of this increased weight and sophistication, the F-15 had to fight off one more set of organizational challenges. Beginning in late 1968, a group of analysts who came to be known as the "Lightweight Fighter Mafia" surfaced with complaints that the aircraft was too expensive, incorporated too much high-risk technology, was unnecessarily complex, and would not achieve its advertised air superiority performance. These analysts, led by Pierre Sprey, observed that fighter combat generally takes place at speeds at or around Mach 1, and therefore proposed an alternative simpler, lighter, less expensive "F-XX" fighter with a top speed in that range and an emphasis entirely on maneuverability. By
this time, however, the Air Force had come to view the F-15 as its core program; all the F-XX succeeded in doing was further uniting all Air Force constituencies behind it.

The Lightweight Fighter proposal resurfaced in 1970, however, as the Lightweight Fighter Mafia realized that perhaps the only way to get their program off the ground was to exploit the dynamics of interservice rivalry. Everest Riccioni, another central player in what would become the development of the F-16, argued explicitly to the Air Force that the Navy was exploring the notion of a low-cost fighter program, and that if the Navy got into the game first, the Air Force might be forced to repeat the experience of the F-4 and buy a Navy-produced plane. In this case, the fighter procurement philosophy and hence the overall force structure of the American Air Force -- the decision to produce a "high-low" mix of relatively small numbers of highly capable, expensive F-15s and relatively austere, cheap F-16s -- was at least in part dictated by the U.S military's institutional structure.

Indeed, the eventual performance characteristics of the F-16 were critically affected by the institutional structure of the procurement process itself. The F-16 initially evolved as only a technology demonstration program, not necessarily intended to result in a missionized weapon system. The procurement strategy selected was one of prototyping, where two different contractors were selected to build one or more
"sample" aircraft and test those aircraft extensively under operational conditions. Only after these tests, the reasoning went, would the Air Force and the Department of Defense decide whether to go into full-scale production. The aim, up front, was simply to experiment with new technologies, evaluate them, and have them available for incorporation into weapon systems, but to stress the development of subsystems and aerodynamic concepts rather than a fully missionized aircraft. The Pentagon clearly had other goals in mind, however, when pursuing this strategy. It could see that the Air Force, as had been the case in the past, would interpret the lightweight fighter as a potential threat to the F-15 program; labeling it a mere technology demonstrator was one way to win the service's acquiescence to the program. That being the case, the Secretary of Defense was also careful to fund the prototype program from his own budget, and not from that of the Air Force, in order to minimize potential service resistance.

The Pentagon's strategy met with great success through the conclusion of the prototype competition. When the decision was made to select one of the prototypes for production, however, and the YF-16 proceeded into full-scale development as the F-16, it was handed over to the Air Force's development and procurement bureaucracies, from which it had been protected until that point. Most analysts agree that the ensuing changes to the aircraft -- the addition of thousands
of pounds of weight, increased size, the additional missions of close air support, interdiction, and nuclear weapons delivery, more armament and advanced avionics, and doubled cost -- perverted it into something very different from the original concept of a cheap, lightweight fighter. The changes significantly degraded its performance as an air-to-air fighter, conveniently reducing its status as a potential competitor to the Air Force's F-15. In other words, the nature of the institutional structure of the procurement bureaucracy, and the Air Force's desire to maintain the F-15 as its central, unchallenged aircraft program, resulted in dramatic changes in the performance parameters of the F-16. Indeed, by the time the initial F-15 production run was complete in 1980, the F-16 had become so heavy and costly that the Air Force, to no one's surprise, resurrected an old McDonnell Douglas proposal to fill out the fighter force with additional F-15s instead of F-16s. These arguments were quickly squelched, however, when the F-16 began to defeat the F-15 in semi-official head-to-head air-to-air test engagements.

The manner in which institutional structures affected the performance norms for the F-117 revolved around the numbers of aircraft produced. Initially, the Air Force had ordered twenty F-117s, which it calculated would be more than sufficient to ensure that an adequate number would be fully mission-ready at any one time for the individual, covert
strikes for which the aircraft had been designed. No one in
the Air Force originally envisioned using any more than ten
aircraft, at most, for any given mission. As the F-117 moved
through the production process, however, it began to attract
support from the Congress as more and more people were told of
its existence and success. Conservatives backed it for
obvious reasons, as did the more moderate military reformers
because of its creative use of high technology, its utility in
situations other than all-out conventional or nuclear war, and
its incredible bombing accuracy. As a result, Congress, which
was responsible for funding the program, directed the Air
Force to acquire an entire wing of the aircraft, which
generally consists of 72 aircraft in four squadrons. The Air
Force was therefore challenged with the task of finding a
mission for this large force of F-117s they were directed to
buy. Apparently, a secret, high-level debate ensued over the
F-117's role, with the result that Congress' numbers were
scaled back; eventually, 59 of the aircraft were built.

Another critical pattern evident in these aircraft
procurement case studies is that U.S. military and procurement
institutions find performance goals sufficiently important to
alter their behavior patterns in reaction to previous
failures. The F-15 procurement strategy, for example, was
selected as a direct and explicit attempt to avoid the
disaster of the F-111 and C-5A procurement programs. Its
strict milestone concept was embodied in a detailed 146-page
contract, with terms, conditions, and restrictions strictly
delineated, rather than reliance on a letter of faith
agreement as had been done with the F-111. Each of the 24
milestones had to be met before progressing to the next, with
real financial incentives and penalties attached. The
Blueline Management System was intended to correct prior
deficiencies in information flow, preventing difficulties with
the aircraft development program from festering at lower
levels before they received appropriate high-level attention.
McDonnell Douglas also accepted a "total system performance"
responsibility clause, which gave the contractor
responsibility for satisfactory integration of the engines and
all other government-furnished equipment. Unlike the previous
experiences, which the Air Force was deliberately attempting
to avoid, the service could decide unilaterally whether the
contractor had met all its commitments, and could delay
funding or cancel the program.

The approach to specific technical details of the F-15
also reflected the desire to avoid the mistakes of the F-111
development program. In response to the F-111's engine-inlet
compatibility problems, for example, the Air Force mapped the
entire engine-inlet interface of the F-15 before its first
flight. Similarly, in the wake of the wing box fatigue
problems of the F-111, major structural testing was conducted
well before the first flight of the F-15. In sum, steps were
taken to make the F-15 program much less concurrent than its
immediate predecessor, with the aim of identifying technical difficulties well before they might cost significant amounts of development funds to correct, and more importantly, well before they could attract significant political attention.

The prototyping philosophy of the F-16 was an even more extreme and deliberate attempt to avoid the pitfalls of high concurrency. The decision to compete the YF-16 and YF-17 was critical in determining the eventual performance parameters of the aircraft. If the competition for full-scale development had been held on paper only, it is likely that the YF-17 would have won simply because few people would have been willing to accept the technical risks inherent in the General Dynamics aircraft.

The pattern is therefore one in which the structure of U.S. defense and procurement institutions acts as a filter through which threats from the international system are interpreted and countered. The performance norms affect, and are affected by, this institutional structure. Performance outcomes for U.S. aircraft were generally enhanced beyond a strictly "rational" response to the Soviet or other threats because of the nature and interactions of the institutions responsible for defining that threat and creating the weapons which responded to it.

The institutional structure of the Soviet Union's defense procurement bureaucracy had a radically different relationship to its performance norms. In short, while the Soviet Air
Force valued technological sophistication and demanded very high performance parameters, the institutional structure of the Soviet defense industry and the incentives embedded within it prevented the realization of those goals. The Soviet Air Force was unable to get the Soviet defense industry to build the weapon systems it wanted to respond to the threats it perceived.

The economic incentives to Soviet weapons designers and producers were little different than those presented to actors throughout the rest of the Soviet economy. Factory managers' decision rules were based on the fact that their success was measured according to fulfillment of plan targets dictated to them by the state. Because of the complexity involved in centralized planning of an economy serving the needs of 250 million, Soviet planners had no choice but to simplify their task by stressing "val," or gross output, plan indicators. Since the planners and the ministries sat atop a vertically integrated production structure in which the planned outputs of one organizations were the necessary and planned inputs of another, they had to insist on the satisfaction of gross output targets in order to keep supply lines functioning. This meant that factories, including those producing fighter aircraft and other military output, were rewarded for simple quantitative plan fulfillment, rather than for quality, reliability, or product mix of output. In addition, the "val" indicators included the value of supplies produced in other
enterprises, and therefore discouraged productivity by encouraged the use of more and more expensive inputs. Even worse, producers were rewarded for producing goods that were made but not sold, removing any incentive to be responsive to consumer needs.

This entire system also mitigated against technological innovation, since factory managers were hesitant to interrupt production in order to introduce advanced technology for fear of falling short of output targets. The nature of the system of material supply similarly fostered technological stagnation. Innovation requires changes in patterns of material inputs, which requires establishing new sources of supply. This is a great risk in a taut planned economy of perpetual shortage. Avoiding innovation minimized supply uncertainty for Soviet managers, therefore ensuring that there would be little difficulty in meeting the all-important quantitative plan targets. Managers also had probably, legally or illegally, stocked working supplies of materials which they had historically had trouble obtaining; they did not want those supplies to go to waste.

The institutional isolation of basic research, applied research, design, development and production also prevented Soviet industry from responding to Air Force requirements. Soviet research institutes constrained weapons design by publishing handbooks that specified not only research results, but also an approved list of structures, design forms,
components, materials, and manufacturing techniques. The design bureaus had to rely on the handbooks to supply day-to-day guidelines on design. The separation of applied research from development meant that the designer could only take from the research institute whatever was available, and could not invent or wait for something new. There were no "buy-ins," and therefore no incentive for fancy designs in the applied research stage. The designers also had to be confident that the chosen technical levels did not present insurmountable design or production problems, or else they would risk the bonuses based on satisfying gross output requirements. The result was a de facto technical freeze on major system components before the weapon was developed. Designers were therefore inclined to employ entire subsystems from previous generations of weapons.

In stark contrast to the competitive dynamics which characterize the U.S. weapons procurement process, the monopoly position of most Soviet defense enterprises allowed them as producers to respond to the vagaries of their own bureaucratic and organizational interests to a much greater degree than to the needs of the armed services. Their focus was on providing jobs for their workers, and on fulfilling the ever-present gross output targets. Cost-effectiveness was not a concern, so that many competing systems were built to accomplish the same mission, and few trade-offs were made as material inputs were allocated to weapons producers. A Soviet
military service was often completely dependent on a single design bureau or production association for a weapon system. Since it had no alternate source of supply, there was little it could do to alter the structure of its situation. Even a former Chief of Staff of the Soviet Air Force has complained openly that the monopoly position of the Ministry of Aviation Industries compelled the Air Force to purchase weapons which were not required and often not wanted. Defense enterprises and producers were interested only in meeting their gross output requirements with the minimum required effort. Because of a lack of competition between design bureaus and production associations, the customer has little alternative but to take what it was given. Occasionally this problem was recognized and competition was nominally attempted, but generally in such cases, when the development of complex and expensive prototypes such as aircraft was begun on a competitive basis, both variants were eventually selected, and effectively analogous items were produced in parallel. The result was a serious lack of combat readiness and effectiveness in the Soviet armed forces. Large numbers of low quality weapons were produced, and their models and types were often completely unstandardized.

Indeed, in many cases the institutional economic incentives led to overproduction, in terms of sheer numbers, far beyond what the Soviet armed services actually requested. One Soviet source reveals, for example, that unnecessary
stockpiles of ballistic missile launchers were built in order to keep factory workers employed and paid bonuses, not for any specific military requirement. Additional missiles, beyond those ordered by the Ministry of Defense, were routinely delivered, just on the initiative of industry. It made sense for the enterprises to maintain the capability to engage in this sort of activity; given the reliability of wholesale supply lines, it was prudent to maintain excess input stocks in order to ensure the ability to meet future production targets.

The Soviet defense industry’s lack of responsiveness to service demands persisted largely because defense managers were not held accountable for the consequences -- often dreadful accidents resulting in injury or even deaths of crew members -- of their behavior. The Main Shipbuilding Directorate of the Navy, for example, was held responsible only for the stages of weapons development beginning with the technical specifications for ship design and ending with the ship being turned over for operation. Completely separate naval organizations were responsible for the ship’s operation until it was decommissioned. Most design bureaus and factories did not even have institutionalized arrangements or facilities for accepting complaints.

The armed forces’ one direct effort to combat the problem of overproduction of ineffective weapons systems was the institutionalization of military representatives in defense
production facilities. Supposedly independent forces for quality control, these "mil reps" were employees of the armed services whose job it was to oversee production and reject output that fell below certain quality standards. Although these representatives were paid their wages by the services, however, they were assigned their housing and other "extra-budgetary" privileges -- child care, vacations, extra foodstuffs, etc. -- not by the military garrisons under whom they were technically employed, but by the enterprise they were designed to oversee. The enterprise management therefore could decide whether or not these people received a decent apartment and other perks based on their loyalty to the factory. Not surprisingly, the military representatives developed a proclivity to "overlook" irregularities they should have reported to the service; they were co-opted by the factories where they worked. Not getting in the way of sufficient and timely delivery of equipment, regardless of quality, became more urgent than their responsibility for quality control.

These findings directly contradict the conventional wisdom that the Soviet Union, responding to historical lessons about the cost of inferiority, chose to stress numbers over technological sophistication and evolved a design philosophy of evolutionary development, commonality, and simplicity. The emphasis on mass, on large numbers of troops and weapons, supposedly was attributable to a fear of uncertainty, a
tendency reinforced by the experience of World War II, when a qualitatively superior German force was defeated with sheer Soviet numbers. Western technological superiority would be deliberately overcome with mass. In addition, the logic goes, the Soviet Union had a strong combined arms tradition dominated historically and bureaucratically by the large, low-tech ground forces. The maintenance of a large standing army was the legacy of a somewhat unstable multinational empire, surrounded by actual or potential enemies, plus the added duty of prosecuting the historical mission for which the USSR was founded. The data presented in this study reveal this conventional wisdom to be fundamentally flawed. The observed quantity-over-quality phenomenon has resulted from the perverse institutional and incentive structure of the Soviet economic system and weapons procurement process, not from a sense of intentionality. In other words, while in the United States the armed services used control over information and expertise to gain control over resources, in the Soviet Union, industry used its control over resources to dictate procurement outcomes.

Japan: Secondary Performance Goals. The case of Japan provides a sharp contrast to that of the United States and the Soviet Union when it comes to the desire to adhere to performance norms. Performance -- in particular, performance in response to any particular threat from the international environment -- has taken a back seat in Japan to other values
of autonomy, diffusion, and nurturance. Indeed, many analysts have speculated that the Japan Defense Agency lacks the skill to assess tactical or operational threat environments and then to set weapons requirements in response. Japanese combat training, for example, is simply not adequate to prepare Japanese troops for effective operation. Crowded conditions force the Air Self-Defense Force's F-15 exercises to be held hundreds of miles off the main island. Pilots almost never gain experience in maneuvers at military speeds because the sudden acceleration would risk putting them in the path of commercial air traffic. They simply do not train under realistic combat conditions. Lack of ammunition means that pilot flying hours run at around 2/3 of U.S Air Force levels; the supply is so tight that many squadrons assign all their practice missiles to one or two pilots, who each fire under varying conditions and then instruct their colleague on the missiles' characteristics.

**Military Technical Norms: Cost**

Japan has similarly subordinated cost efficiency or thrift to other goals. Simply put, Japan will pay more in order to learn how to develop and adapt technology. Defense officials in Tokyo admit, for example, that local development of weapon systems costs two or three times as much as building comparable systems under license, which in turn is roughly twice as expensive, on average, as direct imports. They hope,
however, that co-production or indigenous development will pay
off in the long run as Japanese firms learn valuable
technologies and skills they currently do not possess.

Given that Japan's normative priorities lead it to stress
indigenization and nurturance over cost-effectiveness,
institutional structures have had to evolve in order to keep
the defense budget within its constitutional limits. The
TRDI, according to some analysts, has tried to maximize the
use of private sector resources for the development of defense
technologies, most often issuing contracts to act as seed
money for promising technologies already identified by and
well advanced in the private sector. This situation
minimizes government risk, but the system generally ensures
payoffs to industry through early promises that systems based
on those technologies will eventually be developed. In other
words, companies fund their own R&D projects under the
assumption that ultimately those costs will be reimbursed
through JDA production contracts.

In the United States, despite loud and constant homilies
to the need to improve efficiencies and save money, the
performance norms as outlined above have in reality strongly
outweighed thrift or cost-effectiveness. We have already seen
how organizational battles over resource allocation, generally
related to system definition and service purity, are fought
eyearly and hard in the procurement process. It is also
important to note the degree to which the competitive
institutional structure of the American weapons procurement process leads to early underestimates of program costs and inevitable cost overruns once systems get into production. Known as the "buy-in," the system is one in which contractors spend sometimes huge amounts of their own money up front in order to ensure that their proposal will be the one selected; the contractors present in their bid for the development contract the lowest possible believable estimate of eventual production costs. The contractors realize that once the system gets far enough into the procurement pipeline, the tremendous sunk costs make it extraordinarily difficult for Congress to cancel the program; despite the revelation that their original estimates were completely unrealistic, contractors are still assured of recouping their up-front investment and reaping tremendous profits through production. Because it is simply too expensive to maintain two or more production lines for big-ticket items, the cost-cutting benefits of competition are lost once the production contract is awarded (or, in most cases, once the development contract is awarded, since a system's developer is generally a shoe-in to win the production contract).

The monopolistic Soviet system, although structurally dissimilar in many important aspects, is like the U.S. process in the degree to which it encourages inefficiencies in resource consumption. We have already observed how the gross output targets were often calculated by including the value of
inputs used in the production process, directly encouraging producers to behave in a distinctly non-economizing manner. The institutional incentives toward volume of production rather than quality or technical sophistication also encouraged lavish resource consumption, increasing costs.

The Soviet defense sector enjoyed such high political priority for distribution of scarce resources that it is reasonable to wonder whether the higher levels of political leadership were even aware of the inefficiencies inherent in the defense industry. Because of the nature of the Soviet planning process, resources were allocated in terms of material balances, with rubles generally tacked on in the last stage of the budgetary process as an accounting mechanism. The ruble in the wholesale sector was therefore merely a post-facto accounting device, not a genuine instrument of exchange carrying real, discernible value. This system meant that the Soviet government could in effect assign different ruble values to the same commodities, generally having more to do with political priority than with supply and demand. Since this priority was consistently afforded to the defense sector, defense enterprises were "charged" fewer rubles for the exact same material inputs that might command a completely different, higher ruble "price" in another, less politically important industry. As a result, because resources were never accurately denominated along a single yardstick, it is likely that few, if any, decision makers in the Soviet Union had any
idea of the scope of inefficiency of resource consumption in the defense, or any other, sector.

**Military-Technical Norms: Delivery Schedules**

Again, in Japan, delivery schedule is subordinated to the other norms of autonomy, diffusion, and nurturance. Similarly, in the United States, delivery schedule is certainly not as important as performance goals, and there are frequently explicit trade-offs made to delivery schedules in efforts to lower immediate costs. Stretching out weapon system procurements in the United States is a well-known and oft-practiced method of decreasing the amount of money spent on the advanced development or production of a weapon in any given year; of course, in the long run, this strategy increases total lifetime costs for the system, as economies of scale are not realized, and production lines must be kept open longer in order to produce the same quantity of weapons, or fewer total weapons are purchased.¹

The F-22 development program has been kept alive partially through repeated stretchouts. First, in late September 1992, Air Force acquisition officials decided to trim initial F-22 production from eleven to two planes over the following eight years, with an expected savings of up to half a billion dollars over the life of the engineering and

manufacturing development contract; two months later, the production schedule was further amended with an eighteen-month delay of the start of full-scale production until July of 2001. The latest rephasing proposal, submitted in July of 1993, further delays many parts of EMD for more than a year, and pushes initial operating capability back to the year 2003. The hope is that the adoption of innovative "lean manufacturing" techniques, whenever F-22 production finally begins, will lead to a flat learning curve that might at least reduce the absolute costs of future stretchouts of the program.

Because of the need to meet gross output requirements for a given time period in the Soviet system, delivery time was a critical norm for Soviet weapons designers and producers. Since priority was afforded in the creation of an aircraft to the meeting of specific deadline dates, these was disincentive to slow down the process to correct any problems or flaws that may have cropped up during development. The result, once again, was that first flights would proceed according to predetermined timetables, regardless of whether the system being tested remotely resembled the system that was actually ordered or the system that would eventually be fielded. Indeed, expensive and extensive refinements of weapons had to be undertaken late in the procurement process; the rush to get hardware into the field in order to meet gross output targets and deadlines meant that designs were often given final
modifications during series production and actual field use of equipment rather than during the experimental design and testing phases, when those changes would have been less difficult and costly. In other words, although the Soviet Union may have professed adherence to performance norms above all else, and may have strived for the achievement of cost efficiencies, the norm which best characterizes their behavior in reality is that of delivery time, a consequence of the gross output institutional incentives of their economic system and procurement process.

**Technonational Norms: Autonomy**

In the United States and the Soviet Union, autonomy was taken for granted. The U.S. position as the undisputed leader in most aircraft technologies meant that concern about reliance on foreign know-how was rare. Similarly, although the Soviet intelligence services carried out extensive efforts to acquire Western technologies, those technologies were seldom successfully integrated into the Soviet design and procurement pipeline.²

Japan, however, holds autonomy and indigenization as a primary goal. In writing the initial tactical and technical requirement for the FS-X, for example, Japan clearly attempted to justify a domestic aircraft by writing a requirement so

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unique as to virtually eliminate any existing foreign plane from consideration; the aim was to break away from the co-production and licensing arrangements of the past. Many observers have concluded that the FS-X program was delayed beyond an initial early 1980s start date because Japanese industry knew it was not ready to pursue the project on its own. Instead of settling for the existing procurement relations with the United States for yet another generation of combat aircraft, the JDA and TRDI delayed the need for a new system by implementing a Service Life Extension Program (SLEP) on the F-4J. The F-4J SLEP, along with production of the XT-4 trainer, also gave Japanese industry valuable systems integration experience, and provided industry with ammunition in its battle to persuade unconvinced constituencies that Japan was ready to "go it alone" with an indigenous major aircraft development and production line. For the F-4J SLEP, Mitsubishi Heavy Industries essentially completely rebuilt the aircraft, installing and integrating a completely new, albeit mostly American, avionics suite. Although this program did not provide Japanese industry with the experience of completely designing and building its own aircraft from scratch, the XT-4 program did. A trainer is a good trial program for gaining systems integration experience, since its technologies and integration demands are less demanding and complex than those for a full-fledged fighter. The XT-4 gave the Japanese aircraft industry the credibility and self-
confidence it needed to argue that it could design and produce the FS-X autonomously.

Japan was determined that the FS-X would be all-Japanese. Even after political pressures, largely due to trade tensions with the United States, forced the JDA to consider co-development based on an existing foreign aircraft, American contractors trying to "sell" their systems found themselves repeatedly discouraged by additional lists of detailed specifications tacked on at the last moment -- requirements such as the need to take off in 110-degree heat, even though the temperature has only reached 110 degrees once in Japan in the last century -- that would render existing aircraft inappropriate.

U.S. technical teams repeatedly advised the JDA that some of these FS-X requirements were all wrong, if they were really intended to meet tactical and strategic goals. The Sullivan mission of April 1987, for example, pointed out that the tactical parameters the Japanese had set to perform the stated mission -- securing the Soya Strait between Sakhalin and Hokkaido by using the FS-X to attack Soviet missile firing and troop-carrying ships -- were quite different than those the U.S. would have chosen. The JDA focused on attacking ships once they had breached Japan's twelve-mile sea limit, and planned the load the FS-X with maximum weaponry and fuel for this anti-ship role; the U.S. would have preferred to plan to strike at a greater distance, and focus more heavily on the
possibility of the aircraft's having to perform the secondary roles of dogfighting with Soviet MiG-29s. Indeed, the Americans became convinced that the Japanese Air Self Defense Forces had not engaged its sister services, the naval and ground forces, in discussions on coordination of combat activities and the proposed mission of the FS-X.

In essence, the JDA saw the military mission as already covered by the U.S. F-16s based in Misawa. The Japanese goal was therefore to build a domestic aircraft; after decades of learning from co-production and licensing agreements with the United States, the sentiment within critical Japanese organizational constituencies was that it was time for Japan to build an aircraft of its own. The grudging decision, despite these pressures, to settle for a co-development program based on an existing U.S. fighter was made clearly on the basis of overwhelming political pressure from the United States.

This decision was not made without institutional battles among critical Japanese organizations. Mitsubishi Heavy Industries, in particular, lobbied heavily for domestic development. The company spent the summer and fall of 1987 trying to convince the Japanese government that it was possible to develop and produce the aircraft at home at a competitive price. Mitsubishi's development of a new system of cost control, its expansion of the use of computational aerodynamics in order to demonstrate cost reductions, and its
use of a new computer-aided design system for testing wing characteristics were all intended to strengthen the case for an all-Japanese FS-X. Mitsubishi also argued that its use of technologies in which it claimed Japan had an advantage -- advanced composites, metallurgical processes, some aspects of stealth technology, and control-configured vehicle technologies, among others, would give the FS-X more advanced capabilities and a longer service life. In the end, however, the United States' "buy American" arguments, and the trade and political issues behind then, coupled with the revelation that the Toshiba Machine Corporation had illegally sold submarine-quieting propeller milling machinery to the Soviet Union, lent bureaucratic weight within Japan to the Ministry of Foreign Affairs. The maintenance of good relations with the United States became paramount, and the co-development option prevailed.

Japan did not abandon the indigenization strategy, however, once the co-development option was chosen. Japan simply shifted its emphasis slightly to learning as much as possible about American technology, for purposes of future adaptation -- what Samuels labels "the paradox of autonomy through dependence." While choosing which foreign aircraft would serve as the base aircraft for the co-development program, Japan of course collected data on a variety of options. During this selection process, many in U.S. industry

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feared that Japan’s repeated requests for information on U.S. aircraft were aimed less at making a choice from among American systems than at capitalizing as much as possible on American technologies for their own future development programs. Most observers agree that the F-16 was eventually chosen as the base aircraft, despite initial concerns about the safety of flying with only one engine, because the F-16 offered more room for growth in adding Japanese-developed components, and because Mitsubishi had already worked extensively with McDonnell Douglas on the F-15 co-production program and wanted to see what new it could learn from a different U.S. manufacturer. The JDA may even have hoped that MHI would gain access to U.S. Advanced Tactical Fighter technologies by working with General Dynamics, one of the F-22’s winning team members.

Overall, it is clear that, for immediate purposes of the FS-X development, Japan was most critically interested in acquiring information on the source codes for the flight management and fire control systems. Japanese officials were also adamant about ensuring that work on items which were completely Japanese-developed, such as the single-piece, composite wings, would be performed solely in Japan. In sum, although Japanese industry had to settle for co-development of the FS-X, it certainly did not abandon its long-range pursuit of autonomous aircraft production.
Technonational Norms: Diffusion

Japanese goals were by no means exclusively geared toward the development of an autonomous military aircraft design and production capability; quite the contrary, Japan’s strategy toward the FS-X fighter was pursued within the larger goal of diffusing technology into a broad commercial aircraft industry. In general, Japanese private industry plays a large role in defining technical and tactical requirements for Japanese weapons systems. Industry pursues defense-related research and development projects that it expects to have direct commercial applications, or to serve as catalysts for technological innovations with eventual commercial applications.

This inclination to structure defense spending so that it has a positive impact on the domestic economy has been particularly potent when it comes to the aerospace sector. Indeed, the Japanese military has sustained the Japanese aerospace industry; it procures most than three-quarters of aircraft output. This logic, as intended, bodes well for Japan’s entry into commercial aircraft markets in the future, as "spin-on" of advanced civilian materials and electronics technologies becomes more important to the success of military programs. Defense sales can reduce costs in commercial product lines, letting the military budget bear some of the R&D costs for technologies eventually directed to non-military applications, and can expand the base of commercial
production.

The institutional arrangements in Japanese aerospace industry further this norm of diffusion of technology back and forth between the military and civilian sector; indeed, institutional structures seem to have evolved from a strong sense that no distinctions need or should be made between civilian and military technologies. Even production facilities are shared. A Mitsubishi passenger business aircraft uses much of the same tooling and machinery technologies as the F-15J; in one plant, production of parts for the two aircraft takes place on the same production line. The selection of specific requirements for the FS-X program further illustrates this point. Japan’s insistence, for example, on an active phased array attack radar for the aircraft seemed to many observers to be of limited tactical usefulness. The decision makes more sense when Mitsubishi Electronic Corporation’s need for military demand to provide short-term profitability in order to develop successful commercial applications is taken into account. MELCO has since used those radars for a number of commercial applications, including collision avoidance; U.S. officials have observed that the integrated circuits that power the radar could also be used in pocket telephones, or to operate electronic road maps in automobile dashboards. In support of diffusion strategies, the JDA’s Technical Research and Development Institute (TRDI) has traditionally targeted
technologies not with an eye exclusively toward eventual application to specific weapon systems, but instead has focused on technologies which seem most likely to benefit the civilian sector.

The institutional arrangements through which contractors share development and production work in Japan also support the diffusion of technology. Design and production contracts are generally divided virtually equally among three or four major firms. As Samuels stresses, 4

Japanese prime contractors repeatedly cooperate in major aerospace programs. Each of Japan’s airframe makers has played a role in every major postwar aerospace project, and in engines all major propulsion projects have been carefully coordinated. Although firms compete to become prime contractors, they do so in the knowledge that the competition is not "winner take all." Failed bidders routinely become subcontractors, receive a fixed workshare, and participate in the design or licensing process....A stable division of labor has been achieved in which firms target areas of technological competence in order to continue to participate....The Japanese aircraft business is described by insiders as a cozy "friendship club" in which each participant has, over decades of cooperation, become intimately familiar with the others and their particular engineering capabilities.

For the FS-X, for example, while the prime contractor Mitsubishi Heavy Industries is responsible for portions of the airframe, avionics, flight controls, support equipment, and systems integration, subcontractors Fuji Heavy Industries and Kawasaki Heavy Industries share heavily in the work as well, with the former responsible for the aircraft’s nose, composite wing upper skin, and tail assembly, and the latter developing

4 Samuels, pp. 279-280.
the center fuselage.

The United States has tended to resist diffusion of technologies between the civilian and military sector for purposes of national security; in general, sophisticated military technologies developed for military purposes have been quickly classified and not available for civilian applications. In recent years, advanced commercial technologies have caught up with their military counterparts, and have increasingly found a use in military systems, but there was no explicit effort during the Cold War to diffuse technologies between the military and civilian worlds. Intense competitive pressures between contractors anxious to secure the next major project precluded diffusion of technologies between actors in the private sector.

Institutional structures in the Soviet Union, in particular the ministerial structure which imposed tremendous horizontal isolation between designers and producers who may have been working with related technologies, virtually eliminated any possibilities for diffusion. The Soviet concern for security was so intense that information, particularly concerning technological capabilities and know-how, was a closely guarded secret. Enterprises and production teams in different ministries were completely isolated from one another; they often did not even know of one another's existence. Technological breakthroughs were not communicated among the ministries, and therefore each separate unit spent
a great deal of time reinventing various wheels. Because of the unreliability of supply chains controlled completely by central planners, all of these isolated units essentially tried to achieve autarky, producing all of the parts they might need in order to fulfill their gross output requirements in-house. This "A to Z" approach to manufacturing even went so far as to include the on-site production of nuts and washers at facilities supposedly devoted to the final assembly of major system and their primary components. This small-batch production method was, of course, expensive and grossly inefficient, and was symptomatic of the degree to which technology, indeed information of any kind, remained completely compartmentalized in the Soviet system.

Technonational Norms: Nurturance

The final norm which characterizes Japan's overall approach to technology, and certainly explains its weapons procurement choices, is nurturance of technological and industrial capabilities considered critical for the future. The push for domestic development of the FS-X was certainly motivated, at least in part, by the fact that the FS-X would probably be the only chance to carry out a fighter development project in Japan for the next 25 years. If the Japanese aerospace industry were to continue to develop as a strategically targeted technological and industrial sector, Japan needed to benefit from the experience of at minimum
playing a major role in the design and development of the FS-X.

James Kurth's follow-on imperative arguments certainly support the notion that the United States nurtured its aerospace sector, although for very different reasons than Japan; the United States did not want to maintain broad technological capabilities, but rather the military-technical competence and production capacity to maintain its superpower status. Issues of employment were also paramount for the United States; so many manufacturing jobs were dependent on the aerospace industry that it would have been extraordinarily difficult politically and economically to let major production lines fall idle.

Kurth's arguments also seem applicable to the Soviet case, for reasons quite similar to those in the United States. The institutional control the defense industrial sector had over procurement outputs virtually ensured that factories would always have work; the complete lack of penalty for failure to meet production standards (other than gross output) virtually ensured that all production lines would be maintained. The structure of the gross output targets encouraged, indeed guaranteed, full employment.

Post-Cold War Norms and Institutions

In the post-Cold War period, when the threat environment faced by the United States, Russia, and to a lesser extent,
Japan, is so radically different than it was just a few years ago, it is reasonable to ask whether definitions of and attitudes toward national security, and therefore the norms followed by those who conceptualize and produce weapon systems, are changing as well. If the military-technical norms which defined the superpowers' approach to security were initially conceived as a response to the threat posed by a well-armed enemy in a bipolar world, how are the United States and Russia responding to their new strategic environments? Might either be moving toward a more comprehensive approach to security resembling Japan's? Furthermore, how might changing norms be affecting the institutional structures for weapons design and development in the United States and Russia? Conversely, how might the institutions which each country has inherited from the Cold War period be affecting the evolution of norms; do those institutions in any way constrain the manner and degree to which the United States and Russia are able to adapt to the new global environment?

Similar questions can be posed with regard to Japan. Does Japan perceive itself to be situated in a new strategic environment in the post-Cold War world? If so, how might its definition of security, and hence its adherence to the norms of autonomy, diffusion, and nurturance, be changing? To what, if any, degree will Japan be willing to sacrifice its traditional values in the service of credible, self-generated responses to perceived threats? Must Japan sacrifice
technonational norms in order to become more responsive to military-technical norms?

These sets of questions suggest the wisdom of having selected Japan as a case to examined in this study. The United States and Russia now face a new strategic environment of reduced threats that in many ways, broadly, resembles Japan's. What lessons does Japan offer for the entirely different set of strategic imperatives the U.S. and Russia now face, in a world where comprehensive approaches to security may become the norm?

Performance

Clearly, in the United States, the evaporation of the Soviet threat and resulting decline in resource allocations to defense have dramatically affected the way the performance norm affects weapons procurement behavior. The U.S. has suffered considerable angst as it tries to determine whether and what the significant threats will be in coming years, and how to behave now that it is difficult to maintain even the fiction of a substantial, genuinely dangerous adversary.

The story of the F-22 is illustrative. The F-22 was initially conceived, as we have seen, at least in part in response to the projected numbers and characteristics of a new generation of Soviet aircraft. When those aircraft failed to materialize, and when the Soviet military machine fell apart, the need for a new American fighter came into question.
Clearly the most menacing opponents U.S. fighter aircraft might have to face in the foreseeable future will be other identical U.S. fighters in the hands of potential adversaries. In other words, not merely the F-22's specific performance characteristics, but its very existence has been challenged time and time again in the post-Cold War period.

The first assault on the F-22 came with the Major Aircraft Review (MAR), the Bush administration's early 1990 assessment of aircraft either in the early stages of the procurement pipeline or pending go-ahead decisions. The aim of the review was to determine the trade-offs between moving ahead with new systems that incorporated innovative technologies, such as stealth, or settling for cheaper upgrades of existing systems instead. The major point of debate throughout the MAR was the degree to which the Soviet threat remained potent. The Pentagon, in particular the Joint Chiefs of Staff, was reluctant to change aircraft requirements from the Cold War levels, opting for prudence in the face of a Soviet threat interpreted as still uncertain. Some civilian officials, however, argued strongly that the threat environment had changed sufficiently to allow for changes in the planning for future American aircraft.

The review concluded that enough uncertainty remained to validate the F-22 requirement. Apparently Cold War-era institutional structures, in which the Air Force and other armed services retained a great degree of jurisdiction over
the expertise required to interpret tactical and strategic threats and hence determine operational requirements for weapon systems, prevented new norms for performance from taking hold firmly in U.S. thinking. For example, the MAR failed to address the significant issue of affordability; Pentagon officials claimed that they could not come to grips with this question because they lacked specific details of the military services' long-range budget plans. Similarly, the review examined the possibility of deploying existing aircraft as alternatives to the F-22 on the basis of data supplied exclusively by the Air Force, despite the fact that the service clearly was biased in favor of going ahead with the new aircraft. The Air Force also managed to keep advanced F-15 and F-16 follow-on designs such as the F-15XX Falcon 21 from being evaluated as possible alternatives to the F-22. Indeed, as we have seen during the Cold War period in the case of the F-15, the Air Force and Navy cooperated in order to save one another's prized programs from cancellation in the face of revisions of the Soviet threat and the concomitant budgetary cutbacks.

Throughout the later and constant controversy regarding the need for the F-22, however, questions about the nature and degree of the existing threat recurred again and again. Influential members of Congress wondered why the F-22 remained untouched at the same time that the broader Pentagon acquisition strategy was to cut programs designed solely to
fight the former Soviet Union. In response to this criticism, Air Force officials have occasionally seemed panicked and confused. Some have claimed that the F-22 was never meant to counter the Soviet threat to begin with, but rather was part of a much broader (and still valid) strategy to stay one generation ahead of any potential enemy aircraft. Others have gone out of their way to predict the imminent emergence of sophisticated follow-ons to current Russian fighter air capabilities, regardless of the political and economic situation there. Still others have shifted their concern to upgrades of other Western aircraft that might be sold to combatants in potential hot spots around the world in which United States might become involved.

In other words, as time passes and the diminishing of the Soviet military threat becomes unmistakable, the Air Force and other armed services may be losing the institutional clout that used to accrue with near-monopoly over information and expertise. Suddenly the need to respond precisely and accurately to a specific threat (and hence performance norm) no longer exists; rival institutions, such as Congress and civilians in the Department of Defense, become more powerful in battles over which weapon systems should be built and what characteristics they should have. In other words, control over information no longer so readily translates into control over resource allocations.

The Air Force and Navy have, however, at least so far,
been successful at turning back attempts to impose commonality on their fighter aircraft. Late in 1985 was the first such episode; Congress at that time floated the idea of combining the Air Force's ATF program with the Navy's Advanced Tactical Aircraft, a long-range, heavy-payload aircraft intended for the medium-attack mission, in order to save money. In order to forestall what they viewed as potentially disastrous Congressional interference with their programs, they agreed to a deliberately vague arrangement in which each would consider the other's core program as the basis for as-yet-undefined follow-ons to other systems. In other words, both services were able in 1985 to cooperate to defer serious consideration of commonality in order to protect the single-service integrity of their prized programs.

We have already seen that a similar dynamic took place five years later during the Major Aircraft Review, when the Air Force backed up the Navy, and vice versa, with arguments that the other's aircraft simply would not be adequate; the Clinton administration's 1993 Bottom-Up Review was no different. In joint (and obviously coordinated) testimony during House Armed Services Committee hearings associated with the Bottom-Up Review, the service chiefs spoke with authority on one another's programs. Both argued strongly in favor of the Joint Attack Fighter, a high-end program which would have required quite a few years of research and development, and therefore implied the need to retain each other's core
programs, the F-22 and the Navy’s F/A-18E/F, in the pipeline.

The services’ cooperation in protection of each other’s aircraft was not the only F-22 strategy starkly reminiscent of the days of the F-15. The Air Force also managed to keep a lighter, less expensive alternative to the F-22 on the back burner until the F-22’s full-scale development contract was securely in hand, just as the F-16 was largely ignored by the Air Force until the F-15 was safely into production. The pattern was this: when funding for the F-22 seemed secure, the Air Force argued that the Multi-Role Fighter (MRF) was a logical F-16 follow-on that had to be funded because of the need to replace aging aircraft; when tactical aircraft, and therefore F-22, funding got tight, the service suddenly became satisfied with continued purchases of small numbers of Block 50-model F-16s for the multi-role mission. The Air Force continually rallied to protect the F-22 program, downplaying or ignoring any program that might have challenged it for attention or funding.

The Air Force was forced, however, to compromise to a previously unparalleled extent when it came to the F-22’s final performance characteristics. A Defense Intelligence Agency study released in February of 1993, tasked with examining the threats presented by enemy aircraft and air defense through the year 2005, observed that American fighters face rapidly eroding air-to-air threats at a time when surface-to-air missiles continue to proliferate. The report
explicitly concluded that, since affordability concerns had become paramount, a threat-based investment in the Navy’s air-to-ground A/F-X might be more prudent than continuing with the F-22. The civilian-led Gulf War Air Power Survey reinforced this thinking with its finding that high-end strike aircraft capable of employing laser-guided bombs were highly effective in the Gulf theater.

The Air Force therefore abandoned the pure air-to-air quality of its future front-line fighter, for which it had fought so hard earlier in the procurement program (recall "not a pound for air-to-ground"), and modified the aircraft to carry two joint direct-attack munitions internally and two standoff-attack missiles under the wings. Lockheed’s F-22 program manager has made it clear that the F-22 was not initially intended to provide any kind of strike capability; some industry and Air Force sources predict bitterly that the addition of air-to-ground capability will ruin the F-22’s stealth qualities. The addition of this capability, however, was instrumental in the F-22’s surviving the Bottom-Up Review.

Why, given that a pure strike fighter, the Navy’s A/F-X, was already on the table, did the Bottom-Up Review cancel the A/F-X and alter the F-22 instead? The answer, once again, may have primarily to do with the still considerable institutional clout of the armed services. The Navy was more concerned with protecting the already-established F/A-18E/F than with
lobbying for the A/F-X; in other words, the Navy's stakes in
saving the A/F-X were not as high as the Air Force's in the F-
22. The Air Force therefore "won" in the sense that its top-
priority program survived, but it was forced to compromise, in
fundamental ways, on the aircraft's performance
characteristics to a degree it never had with previous, Cold
War-era aircraft. The services' positions have been eroded as
the Cold War performance norms erode; the institutional
structures inherited from the Cold War, however, with each
service in essence possessing its own air force, still lend
residual power to the Navy and Air Force in competition for
allocations of scarce resources.

The situation in Russia is starkly different. Russian
spokesmen attempt to maintain the fiction that they are still
designing and producing sophisticated, high-technology systems
in keeping with adherence to performance norms, but the
breakdown of even the inefficient Cold War-era institutional
structures has rendered Russia's defense industrial apparatus
incapable of moving forward with new aircraft programs. The
reinterpretation of the external threat, coupled with the
breakdown of the national economic system, has resulted in a
situation where resource allocation to defense procurement has
plummeted. Heads of Russian research institutes and design
bureaus explain that their facilities are now on starvation
diets; military aircraft design bureaus are currently
receiving between 25 and 30 percent of previous levels of
funding. Defense enterprises have cut back on what are now considered non-essential activities. For example, very little testing work is being performed on the few Russian weapon systems in development; when corners have to be cut, extensive tests are one of the first things to go.

The result is a Russian defense industrial establishment no longer unwilling to respond to the requirements set before it by the armed services due to perverse institutional incentives, but unable to do so because of the rapid deterioration of its institutional capacities. Ministry of Defense officials acknowledged this situation to a certain extent with their 1991 announcement that the Air Force would both reduce the numbers and types of aircraft in its inventory, and accelerate the conversion of operational units to multi-role systems. Some Russian designers have claimed that this trend is a response to the constraints placed on numbers of fielded systems by conventional arms control agreements, but an equally plausible explanation is that the resources simply no longer exist to produce aircraft in their former quantity.

The Russian defense establishment has exhibited signs of reevaluation of performance norms, now that priority access to resources no longer guarantees them the ability to respond to any perceived threat. Some of the recent Russian threat assessment literature, for example, clearly attempts to downplay the significance of Western stealth technology,
claiming that the F-117’s performance in the Persian Gulf war was not as spectacular as initially claimed, or that the challenge of detecting stealth weapons is not as intractable as previously thought. It could be that these relaxed assessments of the threat posed by U.S. stealth technology are rationalizations; if the Russian defense industry complex is not capable of responding to a threat, then the logical course of action might be to downplay that threat’s urgency. In fact, Russian fighter pilots interviewed at their bases in late 1991 indicated that they were no longer concerned with the threat form the West, but instead about the possibility that they might have to engage forces from the breakaway republics which have since become independent states. Since these republics are substantially less well equipped and trained than the former U.S. and NATO adversaries, clearly Russia can begin to adhere to performance norms much less demanding than those in the past.

The degree to which Russia has neglected the formation of military doctrine from which the armed services and weapons designers and producers could draw guidance is another stark indication of the diminishing importance of performance norms. Design bureau chiefs have complained that Russia no longer has a clear system for filtering, evaluating, and analyzing concepts to guide the development of armaments programs. The new Russian military doctrine that was finally approved in late 1993 was quite unrealistic in this regard, calling for a
focus of resources on new weapons technologies and materials in order to build, rapidly, new generations of weapons. It is clear, however, that the defense research and development complex simply does not have the wherewithal to implement this concept. The armed services' priorities for several years have been their personnel, more explicitly, the need to provide housing and better living conditions for officers, enlisted men, and their families. We should not expect to see new weapon systems development in response to any new doctrinal formulations; the institutional capacity to do so no longer exists.

There is currently a substantial debate over whether Japan, in the post-Cold War era, will have to start exhibiting genuine concern for performance norms. Throughout the post-war period, Japan has been able to rely on the security umbrella provided by the United States for protection from the Soviet military threat. Now that the Cold War is over, however, and with trade tensions perhaps reshaping the U.S.-Japan alliance, some analysts have begun to question whether and when that umbrella might begin to leak. Certainly Japan is not unique in the degree to which its threat assessment task has become significantly more complex in the wake of the Cold War, since the new environment brings with it diminished certainty and predictability. China and, particularly, the possibility of North Korea's acquisition of nuclear weapons pose new challenges. One of the most interesting benchmarks
to watch over the coming years will be the degree to which
Japan develops skilled and independent threat assessment
capability, begins to respond in direct and strategically
"rational" ways to perceived threats, and behaves more like a
"traditional" military power which adheres to performance
norms.

Cost

The end of the Cold War has prompted all three countries,
albeit to varying degrees, to reduce resource allocations to
defense, requiring them to become more conscious of cost-
efficiency norms. In the United States, as we have seen,
battles over allocation of now-scarce resources still filter
through the defense procurement bureaucracy's institutional
structure. Now that the ability to trump up a threat, and the
need to pile on technological capabilities in order to build
bureaucratic coalitions in favor of a weapon system, no longer
exists, big-ticket items in the United States are being put
under the microscope like never before.

The new situation renders the U.S. Air Force's and other
services' control over expertise somewhat less significant.
If performance norms are fading, then so is the urgent need
for precise and expert responses to immediate threats. The
Air Force can therefore no longer assume that the weapon of
information and expertise will ensure control over resource
allocations. Civilians in the Pentagon, together with the
officials whose responsibility it is to authorize and appropriate funds for weapons programs -- the Congress -- are increasingly asserting their authority in a manner that transcends their often cosmetic efforts to do so in the past. For example, the 1993 defense authorization debates resulted in around $3.3 billion in funding for the Air Force and Navy's three top tactical aircraft programs being left to the discretion of the Secretary of Defense. He was instructed to allocate the money to the program he felt was most technically mature and responsive to current needs. The Congress, it seems, will no longer "take the Air Force's word for it" when it comes to weapon system requirements; the changed threat and declining budgets have led to demands for an independent analytic foundation to support tactical aircraft program decisions.

The Air Force and its prime contractors have displayed a moderate degree of flexibility in adapting to a situation in which resources are not practically unlimited. In order to share development risks and pool development resources, all of the contractors involved in the bidding for the F-22 program decided to team. With defense budgets declining, military aircraft production has become a buyer's market, and the Air Force could afford to set its own terms for the early development contract; the competitors knew they would be lucky if Air Force funds covered half of their costs. The seven firms involved in the Dem/Val competition spent tens of
millions of dollars of their own money, absorbing the risk primarily because they know that this would be the only large fighter contract for at least the next decade. Sharing the risks reduced the potential pain to acceptable levels. The payoff, of course, would come to the winner of the full-scale development and production contract; as long as the institutional arrangements remain such that only one contractor (or contractor team) in effect enjoys a monopoly status once the production contract is awarded, it will prove difficult to stop the "buy-in" and therefore alter the incentives that produce cost overruns.

The Air Force was also careful during the source selection process for the F-22 program to select a "winner" whose proposal was not so ambitious as to lead to technological difficulties, and therefore cost overruns. Indeed, the only guidelines set forth for the fly-off between the airframe prototypes, the YF-22 and YF-23, were that the prototypes should be flown for risk reduction purposes. The actual capabilities to be demonstrated during the source selection flight testing were left to the discretion of the contractor team. In other words, the goal of the flight test program was to establish readiness for low-risk development, not to determine the full capabilities of the aircraft in the classic sense, nor to determine compliance with design requirements or specifications. In fact, the contractors were asked to specify pre-flight predictions of various performance
characteristics against which the Air Force would be able to compare actual test results. In essence, therefore, the flight test program was not a flyoff, in which the performance of the competing aircraft were compared directly, but a data collection exercise through which the contractors tried to convince the Air Force that they could accomplish what they had proposed with the lest technical, development, and therefore financial risk.

The situation in Russia obviously is much more extreme than that in the United States. Control over resource allocation has been taken completely out of the hands of the industrial sector and placed firmly with the civilian leadership. In spending the very little money available for anything at all, the fledgling Russian legislative and executive branches have been aggressive and unrepentant in their defense spending cuts; the armed services and organizations in the defense industrial sector have very few institutional levers which with to combat their own disintegration.

As a result, Russian defense industrial institutions have been forced to pursue a wide variety of coping strategies, most of which have met with at best modest success. The most prominent of these, conversion, assumes that defense industrial manpower, physical plant, and technology can be profitably transferred to the civilian sector in an era of reduced allocations for the military. The actual course of
conversion in Russia, however, has been one in which military orders have been decreased suddenly and without warning, with defense enterprises on their own to find civilian products to fill the gap. Some aerospace design bureaus, because of institutional histories involving design and production of civilian as well as military aircraft during the Soviet period, have a leg up on the others; most have been left bewildered and frustrated, and in many cases furious, with their new situations.

Russian institutions have defined their primary difficulty with conversion as the lack of start-up funding. Retooling military production lines for civilian purposes is expensive, and for the first several years of conversion, help from the government was not forthcoming. By 1992, the state budget included modest sums for this purpose, but most observers agreed that the amounts appropriated were only a fraction of what was required. Russia therefore turned to an alternate conversion strategy involving the arms trade. Arms sales are to provide a source of capital, with the proceeds subsequently used to finance the conversion of defense enterprises not producing for export. Many Russian defense enterprise representatives and government officials argue that they have no alternative but to export weapons to earn revenue to keep their businesses alive. The Russian State Counselor for Conversion has estimated the potential Russian defense export market at around $4 billion for conventional systems,
with the potential to escalate to three times that amount if they target for export some of their most technologically advanced systems. Officials stress that Russia will not try to sell products that are not competitive in the global market, but that they see nothing wrong with dumping; they specifically mention the possibility of sales at a price 15% below the average market.

In addition to arms sales, defense enterprises have also become almost completely preoccupied with the search for independent sources of financing for their defense and new civilian activities. The search for private capital has led a number of leading aviation enterprises to combine into joint stock companies. Some design bureaus and production organizations have also been given a tentative green light to move ahead with privatization over a several-year transition period.

Russian defense institutions clearly have hoped that new institutional arrangements will improve their positions in this scramble for capital. Because the production associations, for example, are in a considerably better position in the new environment because their product is more saleable than that of the research institutions or design bureaus, the latter are forming special agreements or mergers with them. These streamlined operations, it is hoped, will not only combat the old problem of institutional isolation, but will also guarantee the health of sagging research and
design organizations.

Perhaps the defense industrial sector's primary hope lies in the search for foreign capital. The research institutes, which find that there is virtually no Russian market for their services in that environment of stagnant technology, in particular find their futures increasingly tied to international orders. Aircraft design bureaus find that their most promising match marries Russian airframes and Western engines. Mikoyan has even approached the United States about the possibility of teaming with a Belgian firm to enter an open international competition to provide trainer aircraft for the U.S. Air Force. Mikoyan has also recognized that a substantial part of its foreign aircraft market might be for upgrades of older Russian aircraft currently in service in other countries. Indeed, some Russian aerospace research institutes seem to have concluded that the best way to penetrate Western markets is to form joint ventures with Western firms.

Most of these independent efforts by Russian defense industrial institutions to find palatable strategies for dealing with their new environment have been at least partially thwarted either by the organizations' lack of experience or competence, the lack of a stable institutional and legal structure within which to conduct business, or the government's reluctance to relinquish any of its newly-acquired control over defense resources. In addressing the
first two points, many observers have complained that until Russian defense enterprises and managers, and indeed the Russian government, learn to be more professional in their dealings with Western firms, their benefits from such partnerships will be limited. Potential Western partners have been frustrated by doubts about who owns what, who has the authority to sell it, how valid signed contracts turn out to be, and a lack of recourse when contracts are not fulfilled. Even basic information about research and production facilities -- names, addresses, phone numbers -- were not part of the public record during the Soviet period; Russian officials are still in the early stages of such rudimentary marketing activities as compiling an aerospace directory. Their early track record at critical events like international trade shows has risked earning them the label of nuisance; the Moscow Aerospace '93 air exhibition was infamous for being poorly organized and run.

Equally critical to the success of Russian defense industrial institutions' coping strategies is the tight grip the government has maintained over scarce resources. When arms are successfully exported, for example, the degree to which the state maintains organizational and administrative control over the terms of sale and distribution of revenues has led aircraft manufacturers to accuse the government of "robbery." Most hard currency revenue from arms sales goes straight into the government budget; the rest tends to be
allocated to the production facilities, not the design bureaus and research institutes.

For the first time, the state is also imposing competition on the former monopoly design bureaus and production facilities. Four major Russian design bureaus, for example, competed for the design of the Air Force's next advanced trainer aircraft. Only the first two firms survived the initial cut, and Yakovlev won the final round. The Air Force had originally intended to conduct a flyoff between the two finalists, but there was insufficient funding for two prototypes, and therefore only Yakovlev's winning design will be translated into a flying prototype.

The literal abandonment of the research institutes and design bureaus by the state has also increased the level of politicization of the Russian weapons design and procurement process. Personal ties and political skill, in particular, access to and favor with top government officials, currently play an enormous role in determining the fate of Russian defense industrial establishments. The favored position of the Sukhoy design bureau, for example, apparently has much to do with the political clout of its chief designer, Mikhail Simonov; top fighter and bomber designers repeatedly approach Yeltsin with plans to restart production of new Russian front-line fighters. Because of the resulting informality, military aircraft and helicopter programs move in and out of favor on almost a monthly basis, creating poor morale and an inability
to plan ahead in design bureaus and production facilities. In late 1993, a panel of leading Air Force and industry officials allied in a presentation of a draft plan to prioritize Air Force programs into the 21st century; clearly this constitutes an attempt among these military and industry officials to use their expertise to re-establish some influence over resource allocation. It remains to be seen how successful this strategy will be.

In Japan, FS-X costs have escalated to make the aircraft the most expensive military program in Japan's history. Will Japan be willing, or forced, at least temporarily to downplay autonomy and nurturance norms? In other words, will Japan have to give up the FS-X program because of the unwelcome intrusion of cost norms? Even if that occurs, it will have been the case that Japan has already gained a tremendous amount of skill and technology from the FS-X program. The need to be thrifty may force Japan to compromise on the pace and degree to which it accomplishes autonomy and nurturance, but those norms will not have been jettisoned altogether.

**Delivery schedule**

As we have demonstrated, Russia currently has little in the procurement pipeline. Because of the lack of resources, the design bureaus are churning out easily affordable paper designs rather than viable aircraft programs that will ever have a chance of entering full-scale development. Most of the
next-generation Russian aircraft programs rumored in the West to have been in existence for several years have in fact never made it off the drawing board due to lack of government interest and funding. Delivery norms therefore become moot; there is nothing to deliver.

Japanese adherence to the norms of autonomy, diffusion, and nurturance still outweighs the need to get a system into the field quickly; indeed, the unanticipated difficulties with the FS-X codevelopment program have resulted in stretchouts in addition to cost overruns. If Japan begins to respond, however, to performance norms, then we might expect some urgency in its efforts to field weapons in a timely manner, depending on how potent its considers the immediate perceived threats to be.

In the United States, a curious logic surrounds post-Cold War delivery schedule norms. On the one hand, as we have seen, tight resources have led to the types of stretchouts for the F-22 that have always characterized U.S. procurement behavior. On the other hand, in order to get a new system securely into the pipeline, the armed services and contractors are realizing that it is prudent to push systems through the procurement process as rapidly as possible. This motivation may have been behind the selection of the prototyping procurement strategy for the F-22. Although initially, planners had judged that a prototype competition would be too expensive, the amended approach permitted the first flight of
test aircraft almost two years earlier than had been originally planned. The result was an early design freeze to allow time for prototype construction, so that the YF-22 and YF-23 embodied far less advanced technology than would otherwise have been the case. If, however, program officials correctly perceived that budgetary restrictions would get tighter and tighter in the months and years to come, the strategy was a shrewd one. Congress is much less likely to cancel a program in which substantial funds have already been invested, and particularly one in which impressive flying prototypes have captured the public eye.

**Autonomy**

Autonomy is still quite important to Japan; if anything, this norm becomes even more critical now that it at least seems plausible that Japan will become less reliant on the U.S. security umbrella. When coupled with U.S.-Japanese trade tensions, recent Japanese perceptions of the inferiority of Western technology, and persistent threats from various points on the Pacific Rim, Japan will certainly not downgrade its attention to indigenization of technology.

As we have seen, Russia, in its all-consuming search for capital and investment resources, is desperate to abandon autonomy. Russia's scramble to join the international arms market and to attract foreign investment and Western partners for joint ventures clearly indicates that Russian decision
makers value survival far above independence. The United States, in an attempt to maintain industrial health, is also to some degree downplaying autonomy norms. It seems to be doing so via two strategies: its pursuit of the international arms market, and its foray into joint weapons production with firms from different nations. For both the U.S. and Russia, there are potentially adverse consequences to this survival tactic. First, there is the potential for incompatibility between the goals of states wishing to buy arms and those of American or Russian national security. Care will have to be exercised to guard against the transfer of sophisticated weapon systems to potential adversaries or to conflict-prone regions. Furthermore, reliance on foreign revenues, or even worse, foreign partners, creates dependencies. Should unexpected conflict among former partners arise, U.S. or Russian defense industry could suffer from having transferred sensitive technologies through the teaming process, or it could simply experience a lack of necessary surge capability because of the dispersal of industrial resources around the globe.

Diffusion

Japan's position as one of the world's preeminent economic superpowers, and its success in having deliberately sought that position, renders it unlikely that it will abandon the diffusion strategy that largely contributed to that
success. Russia, in fact, is desperate to emulate Japan in this regard; Russian defense industry leaders explicitly speak of an emphasis on dual-use technologies in order to maintain both military mobilization capacity and a national industrial policy. Russia is desperate to adopt "overnight diffusion," in the form of rapid conversion of defense capacity to civilian production, as a last-gasp attempt to find a productive use for decaying defense resources. We have observed, however, that at least in the near term it will be difficult for Russia to marshal the resources and create the institutional structure necessary to accomplish these goals in an effective manner. For the time being, and unfortunately for Russia, chaos will de facto remain the predominant norm.

The United States has begun aggressively to pursue diffusion strategies. For the F-22 procurement, for example, contractor teaming is intended to diffuse technologies and reduce technological and financial risks between major actors -- military-to-military diffusion. Perhaps more problematic is the U.S. defense industry's attempt to penetrate non-defense markets, in other words, to attempt diffusion between the defense and civilian sectors. Commercial markets are certainly attractive to traditional defense producers in an era of scarce resources; they promise more sustained growth potential. The defense firms most challenged by the need to diversify are those such as General Dynamics and Grumman, whose business is primarily military and with the federal
government, rather than those with a tradition of commercial orientation such as Westinghouse or General Motors. The U.S. government may support this trend; the Clinton administration, for example, recently offered financial backing for research and development of flat panel display technology, initially for commercial applications, but with an explicit eye for future military uses.

Existing institutional structures may slow the crescendo of diffusion activity in the United States defense sector. Even within those defense firms that have also enjoyed a history of commercial business, generally the defense and non-defense sectors have remained relatively isolated, in terms of both plant and personnel. In other words, even within Westinghouse and General Motors, military producers have become accustomed to selling unique products to a single buyer. Their corporate cultures, managerial practices, and approaches to technology are completely foreign to a commercial world responsive solely to the market. Radically different cost, overhead, and business practices are necessary in most commercial areas. It seems likely, therefore, that the defense firms who diversify most successfully will be those who capitalize on their historical technological strengths, moving into familiar technology areas and acquiring existing companies rather than launching brand new start-up

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Nurturance

As with the other two technonational norms, it is unsurprising that Japan shows little evidence of abandoning its emphasis on nurturing strategically targeted industries. Again, the Russian pattern copies Japan, although again within the completely different Russian context. The Russian government, despite its desperate budget deficit crisis, continues to subsidize defense industrial enterprises -- not to support weapons development or production work, but simply to maintain the payment of salaries to workers. When government funds are not forthcoming, production enterprises independently do the same. As of mid-1992, producers had accumulated bank loans totalling around four billion rubles just to pay wages. Even Russian hopes to introduce competitive practices to its weapons procurement processes have been sacrificed to continued nurturance goals; the purchase of both the Kamov and Mil attack helicopter lines, even though the former defeated the latter in three consecutive fly-offs, illustrates the degree to which the state clearly is not yet ready to suffer the political consequences of the unemployment likely to result from the shutdown of major aircraft and production lines. Persisting in these policies is, of course, inflationary, and only prolongs the political and economic agony in the long run.
For both Russia and the United States, one of the key indicators over the coming years will be the degree to which design bureaus, research facilities, production associations, and defense contractors are permitted to die. The United States, thus far, has been only marginally more willing to abandon its defense workers than has Russia, and for a similar reason -- fear of the political consequences of unemployment. We have already seen, for example, that the F-22 development program persists despite general agreement that the threat on which it was based is not going to materialize; however, this may have more to do with the Air Force's success in lobbying for the aircraft than with a grand strategy to preserve the military aircraft industry.

Clearly, the U.S. defense industry is in the midst of a painful process of downsizing; some major contractors have already merged, and others may be eliminated altogether. As a result, it is likely that Darwin's logic will prevail; the stronger, more diverse companies will be the ones to survive. "These...trends could positively influence the defense industry by creating a leaner, meaner, more efficient industry in which foreign competition further stimulates innovation and improves quality."  

Lessons for the Future: Convergence of Norms

The United States, Japan, and Russia are experiencing a

6 Mandel, p. 191.
convergence of national security norms. Japan, although within the context of continued adherence to technonational norms, is moving toward a greater concern for performance and cost considerations. In parallel with Japan's experience, the United States and Russia have moved away from their former near-obsession with performance, toward consideration of an even greater (and qualitatively different) stress on nurturance than has been the case in the past, and also toward strategies emphasizing diffusion and cost considerations.

The former U.S. stress on performance has clearly diminished due to increased attention to cost. The evolving defense industrial environment in the United States has forced many firms to focus on second source contracts or contracts simply to upgrade existing equipment. With defense budgets tightening, it is no longer practical for firms to bear the risk of the investment in research and development necessary to achieve top performance specifications; it is increasingly unlikely that they will be able to recoup those investments with lucrative production contracts. The continued prevalence of some forms of fixed-price research and development contracts exacerbates this problem. In the words of Jacques Naviaux, director of marketing for the Hughes Radar Systems Group, "Today, you can't afford to take a risk. If you push technology, you're going to have some failures. Now, there's no tolerance for failure -- either in government, or in
industry."\(^7\) The institutional structure of the U.S. procurement system, therefore, no longer rewards the piling on of more and more sophisticated technologies. Instead, weapons developers are responding to incentives that encourage them to exercise caution and let someone else bear the risks of pushing the margins of new technologies. According to one aerospace executive, "There's no aggressiveness anymore, no initiative. The military -- or government -- has finally kicked that out of the companies. They've destroyed the willingness to risk."\(^8\)

Fueling this contractor risk-aversion is the U.S. military's vague definition of defense priorities.\(^9\) With future procurement needs ill-defined, contractors are forced to guess about where to invest increasingly scarce research and development dollars. With returns on those investments at best five to ten years down the road, defense firms are understandably frustrated with repeated false starts and the lack of a plan of action to buttress the defense industrial and R&D base. In other words, performance norms are rapidly


disintegrating. The vanishing threat has led to decreased resource allocation to defense, which has made performance secondary to other considerations -- essentially, basic health and even survival -- for U.S. defense firms.

Indeed, these concerns have led to strong calls from U.S. defense industry to adopt explicit nurturing strategies. Of course, the United States has always nurtured its defense industries. When defense research and development reached its peak in the mid-1960s, it accounted for nearly half of all total national research spending, and 80 percent of all federally sponsored science. Federal funding for science and engineering education has also been a tacit form of nurturance of defense industrial capability. The Pentagon has explicitly maintained more than the required number of design teams and assembly lines for critical weapons systems, such as fighter aircraft airframes and engines.

The current debate, however, centers on a qualitatively different type of nurturance, in many ways similar to the traditional technonational Japanese approach. It ranges from the Aerospace Industries Association of America (AIA) call for increased federal funding for eight targeted "critical" fields

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10 Interview with Harvey Brooks and Lewis Branscomb, "Rethinking the Military's Role in the Economy," Technology Review, August/September 1989, p. 56.

of generic research,\textsuperscript{12} to demands for stronger and more consistent political support for U.S. weapons exports, to strategies involving the Department of Defense developing a national plan for both military and commercial products and technologies to maintain the global competitiveness of the U.S. defense industry.\textsuperscript{13} The latter strategy explicitly involves a national industrial policy which, in the words of Malcolm Currie, chairman and CEO of Hughes Aircraft, responds to a situation where the post-Cold War peace is "not a transition from military confrontation to tranquility and prosperity, but from military confrontation to economic warfare -- based largely on technology-related issues -- in which our future prosperity is surely at stake."\textsuperscript{14} Clearly Currie's comments reflect a potentially evolving comprehensive approach to national security in the United States, very much resembling Japan's technonationalism.

Many defense suppliers, however, have been disappointed that their calls for nurturance have not yet been heeded. A 1991 Office of Technology Assessment report confirmed that defense industry adjustment to the post-Cold War environment


\textsuperscript{14} Quoted in Bruce A. Smith, "Currie Calls for Industrial Policy to Bolster High-Technology Companies," \textit{Aviation Week and Space Technology}, 3 December 1990, p. 76.
had been largely ad hoc, left to market forces, and that without concerted action, the United States risked excessive reliance on other countries for critical defense technologies, and a reduction of the industrial base to single-source producers of key weapons systems. A "Project Air Force" report from the Rand Corporation issued the following year similarly argued that, without concerted action, the quality of future U.S. aircraft design capability would be at risk. Even when the U.S. government considers fledgling nurturing strategies, it becomes obvious that no clear-cut goals have been formulated for these strategies; the focus alternates between saving defense-related jobs, retraining workers for new, civilian high-technology jobs, maintaining defense design and/or production capacity, and maintaining generic high-technology design and/or production capability.

Some aerospace research firms, however, without the government enticing them to do so, have begun to collaborate to develop the technology they believe they need to maintain critical design capabilities and counter increased competition from abroad. The National Center for Advanced Technologies,

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a California-based composite materials consortium, takes advantage of recently relaxed anti-trust laws to pool research and share results -- again, a very Japanese-sounding set of behaviors. Indeed, many industry spokesmen define "industrial policy" as simply as a relaxation of what they view as prohibitively intrusive anti-trust statutes, and adoption of favorable tax policies to support and encourage investment in new technologies.\(^{18}\)

Teaming among defense firms, as we have seen with the competitors for the F-22 contract, is another strategy for maintaining defense industrial health. Increasingly, however, teaming is being adopted as a delaying tactic, a way to continue business as usual without fully recognizing that the new strategic and business environment is permanent. Many firms cling to the expectation that "the threat" will soon re-emerge, with a concomitant swift return to the thriving opportunities of the early 1980s. Realistic threat assessment, however, fails to support this rather desperate hope.

Unless nurturing strategies are successfully adopted in the United States, most analysts agree, suppliers will be forced to drop out of the market. This situation, brought about initially because of increased attention to cost norms, could ironically backfire in the long run because of the

tendency of monopoly producers to raise ultimate costs. Indeed, as both the U.S. and Russian defense industries downsize and restructure, there may be lessons each can learn from the other’s tradition of competitive versus monopoly procurement processes. The inefficient, wasteful, unresponsive Soviet monopoly structure precluded its successful harnessing of technology; if the United States permits too many defense firms to drop out of the market, it may risk similar difficulties. Of course, we have already observed that the American procurement process suffers from corresponding structural problems associated with the monopoly position of contractors once development or production contracts are awarded, but with glaringly different results. The "buy-in" imperative results in goldplating and severe cost overruns once the systems’ real costs are revealed. Obviously, with defense budgets slashed, neither the U.S. nor Russia will have the resources to maintain competitive production lines throughout a system’s procurement in order to keep costs down. Both will have to adapt with new and innovative institutions and processes if defense design and production are to become or remain efficient, an imperative even more stringent now that neither country can solve procurement problems by throwing additional resources at them. Perhaps Japan’s example of equal work-sharing among prime contractors can serve as a model.

While performance norms are on the decline in the United
States and Russia, they are in ascendance in Japan. We have established that is unlikely that Japan will stray from its traditional focus on autonomy, diffusion, and nurturance; those priorities predate the Cold War and remain deeply embedded in Japan's approach to national security. What remains to be seen is the degree to which, within the technonational context, Japan will start to pay heed to norms of performance, cost, and delivery as well. Most likely, Japan can be expected, in the post-Cold War world, to devote slightly more attention to independent threat assessment activity, and certainly more attention to spin-on (civilian to military) as well as spin-off (military to civilian) technologies, but always to maintain an explicit commitment to the notion that technology itself is singularly neither military nor civilian, and that it can always be strategically harvested for a variety of applications. Already, in response to the North Korean threat, Japan has reorganized its intelligence bureaucracy and deployed new, independent surveillance technologies, a clear indication that performance norms are growing in importance. Japan has begun to take strictly military threats to its national security seriously, and has begun to respond to those threats in a narrowly military-technical manner. As Japan considers whether or not to become a military power, however, it is unlikely to abandon the normative foundation which gave it the luxury of the capability to consider that decision.
As performance norms decline in the United States and Russia, those countries also consider adopting diffusion strategies. We have already seen that Russia's attempts at diversification and conversion have thus far met with limited success. A few reports indicate that American firms' efforts in this direction have been more positive. A 1991 survey of top executives at over 100 defense companies found that nearly half of the commercial ventures they had attempted in the previous five years had been successful, and that the majority planned to study or pursue commercial markets in the future.¹⁹ Most observers agree, however, that proclamations of military-civilian integration in the United States are premature. Most U.S. companies that do both military and civilian work keep them separate, in isolated plants or independent divisions, in order to maintain compliance with the Department of Defense's security and auditing rules. The Defense Conversion Commission recommended in 1993 that, in order to encourage diffusion strategies, the Pentagon must revise its current procurement laws and regulations to place them more in line with current commercial practices, change its overhead allocation practices, expand the use of cooperative research and development agreements (CRDAs) between government laboratories and private companies, and create an office within the Pentagon to coordinate technology transfer

activities between government agencies and promote dual-use technologies, products, and processes.\textsuperscript{20} Of course, U.S. and Russian defense manufacturers alike will also have to adopt a mentality of cost-consciousness and detailed responsiveness to customer preferences in order to succeed in the civilian marketplace. Clearly, while norms are converging and the U.S. and Russia move toward a desire to adopt diffusion behavior, institutional structures will have to be flexible and adaptive in order to achieve anything near the historical Japanese success in dual-use, spin-on/spin-off strategies.

The United States and Russia are also moving away from their previously assumed autonomy in national security. As we have already observed, Russia is willfully sacrificing autonomy for the sake of survival; virtually any measures which increase the inflow of foreign capital are deemed acceptable in today's Russia. More surprising is the similar dynamic in the United States. Although to a far more limited extent, the U.S. national security autonomy may be in danger of eroding due to foreign purchases of U.S. defense companies, and increasing tendencies by U.S. defense firms to team with foreign partners to reduce financial risks. The relatively low exchange value of the dollar is a strong inducement to buy into the U.S. defense market. From 1988 to 1991, foreign concerns acquired more than 20 U.S. aerospace corporations,

100 U.S. computer corporations, 45 U.S. semiconductor companies, and 35 U.S. advanced materials businesses. Japanese companies made most of these acquisitions. Indeed, the need to "take appropriate steps to protect [the defense industry] from foreign domination" is one of the primary justifications often cited for the establishment of a national defense industrial policy.\textsuperscript{21}

It is clear that institutional structures will play a defining role in determining the success of these new technonational strategies in the United States and Russia. In particular, the adoption of a more comprehensive approach to national security -- where the economic and military components of security merit equal consideration -- in the United States and Russia will require institutional adaptation and flexibility. Ironically, Russia may find itself at an advantage in this transition. Its old, Cold War-era institutions have been largely pulled up by the roots, and it has the "luxury" of starting from scratch. So far, however, Russia has yet to fashion the necessary institutional structure to achieve success in the nurturing and diffusion strategies it has attempted.

In the United States, however, the legacy of existing Cold War institutions imparts varying degrees of inertia to

the post-Cold War adjustment period. The armed services and contractors, as organizations, will have to adopt new standard operating procedures. If this process is not to be protracted and painful, they will have to undergo this innovation without first experiencing traumatic failure. For instance, budgetary pressures may finally mean that the U.S. military's four air forces will be pared down to two, or one, perhaps in the form of a central aircraft purchasing bureaucracy -- the Air Force and Navy will no longer "win" the struggle over commonality. We have seen that the post-Cold War Air Force has already had to compromise on one of its fundamental principles, the single-mission quality of the F-22; even though it has managed so far to retain the single-service integrity of the aircraft, it must see the handwriting on the wall. The armed services are losing the institutional clout that used to accrue with control over information and expertise.

If performance norms were still paramount, of course, then the services would have a case for the importance of maintaining separate aircraft. From the services' perspective, commonality was a threat not only to organizational autonomy, but also to their ability to perform their distinct missions at full capacity. Naval fighters are considerably different in design and mission from land-based fighters. High sink rate landings and catapult takeoffs on and off carriers mean that naval aircraft must withstand intense vertical and fore and aft stresses. The avionics,
sensors, and weapons carriage, along with the mountings for these components, must be designed to withstand these shocks routinely. Attention to compactness in design is also an issue. Because space is at a premium on a carrier, for example, a Navy fighter must be designed for vertical engine changes, rather than simply removing the engine from the rear as is done with land-based fighters. Naval fighter missions are also quite different from Air Force missions. The Air Force generally envisions broad, well-supported fighter sweeps; naval fighters' missions are more specific, to intercept incoming bombers and missiles well away from their carriers, and therefore they must operate much more independently over enemy territory. Naval fighters must be more heavily armed to carry out more sustained combat. Now that performance norms have been placed on the back burner, however, these concerns become considerably less pressing; the justifications for such monumental expenditures of resources lose their validity.

Where Do We Go From Here?

This study has focused on a relatively narrow set of cases in order to examine the broad theoretical questions it poses. An expansion of this work might follow a variety of different directions. Certainly, a longer time series of cases for the United States and Soviet Union might indicate
whether the F-15, F-16, F-117, F-22, MiG-29, and Su-27 are outliers, or if the patterns observed in these aircraft extend back several decades to the origins of air power. Naval aircraft might also be explicitly included in an expanded study; in this way, it might be determined whether Air Force organizational behavior in the United States is atypical, or if armed services in general exhibit the patterns observed here. Of course, aircraft other than fighters, or weapons systems other than aircraft, could be systematically studied. In addition, other countries could be included. Now that Japan has been identified as a special case because of its comprehensive approach to national security, it might be illuminating to ask whether other non-superpowers have done the same. It is also conceivable that non-superpowers, both client states and non-client states, behave in more general terms in patterns different than military giants. Attempts to elucidate patterns among small and medium-sized powers would probably find Israel, Brazil, and several of the Western European countries of particular interest.

Another direction for building on this work might involve differentiation between innovative and incremental technological innovations and their incorporation into weapons system choices. Previous analysis has suggested that different incentives drive the weapons procurement process depending on the types of technologies involved. For example, Jonathan Stein has contended that technological imperatives
are at work in the case of gradual or evolutionary technological change, but government policy based on rational assessments of the international situation govern the advent of revolutionary technologies and their application in major weapon systems developments.\textsuperscript{22} In order to test this proposition, a replicable methodology would have to be devised to categorize technologies as "evolutionary" and "revolutionary," and a means would have to be found to treat weapons systems which embody several or many different types of technologies. Another way of expanding the current study might be to hypothesize that "high" technology, such as that embodied in advanced aircraft, behaves differently than "low" technology, such as that found in rifles or some tracked vehicles.

Finally, in order to get at the broad questions of the drivers of weapons system choices, this study could be expanded to include the non-cases -- in other words, cases in which a hostile threat environment engendered no response, or cases in which a response was generated even though the threat was non-existent. By defining the study in terms of case studies of fighter aircraft which were built, the former set of cases (the upper right-hand box, in Table 9.1 below) is explicitly eliminated from consideration, and the danger always exists of succumbing to ad hoc rationalizations of pre-

existing threats in the latter (the lower left-hand box). Although the lower right-hand box is not of interest, only a study which focuses on all of the other three sets of possibilities is truly a methodologically complete approach to the question of sources of weapons procurement choices.

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Why Study Weapons Procurement Anymore?

The final issue that this study must address is its own relevance. In the post-Cold War world, when the United States and the Soviet Union are no longer engaged in a potentially disastrous and certainly expensive arms race, why are questions about the sources of weapons procurement policies important? Two answers can be offered to this question. First, it is somewhat naive to conclude that the end of the Cold War will result in a world free of conflict and therefore the end of the need for weapons systems. Indeed, the need will be for weapons systems even more carefully conceived and procured, given the scarcity of resources for their development and the unpredictability of the scenarios in which they might be used. A focus on the changing national security
norms and institutions which characterize and influence weapons procurement behavior can help us intelligently to understand, guide, and predict future weapons acquisitions.

This line of argument leads to the other reason the results of this study are perhaps even more important and policy-relevant now than ever before. With resources for defense procurement so limited, policy makers must exercise careful judgment in deciding how those resources will be allocated. Presumably they will try to respond rationally to their perceptions of a new and always-changing international threat environment. This study shows, however, that the weapons procurement process possesses a logic of its own, particularly once systems get to the advanced design and production stage, that is responsive to factors other than external threats. If weapons procurement processes are to be reformed in ways that are truly meaningful, rather than simply as a political sham designed to assuage journalists and politicians once again irate over $400 coffee pots, then the real dynamics of those processes must first be well understood. Reform efforts, as difficult as those might be, will have serious results only if they tackle the true sources of weapons procurement choices, at all stages of the design and procurement process.
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